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MANUFACTURING METHODS AND TECHNOLOGY. PROJECT SUMMARY REPORTS.(U)
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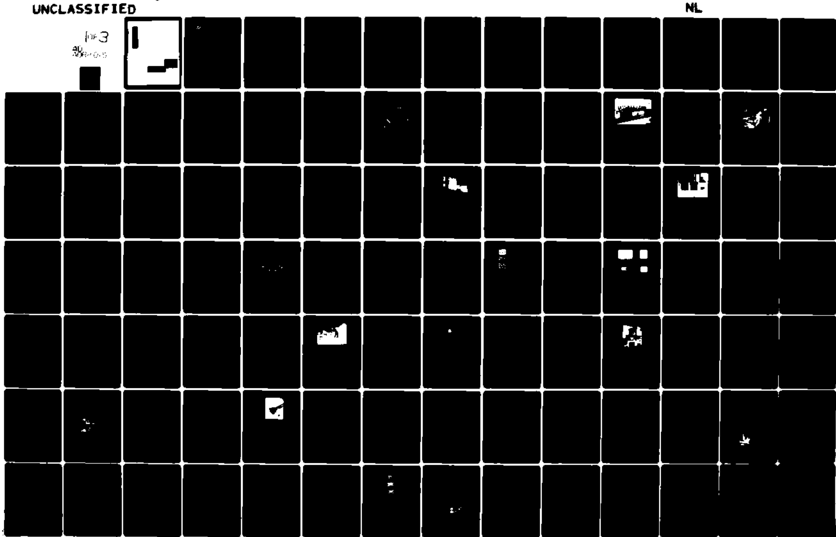

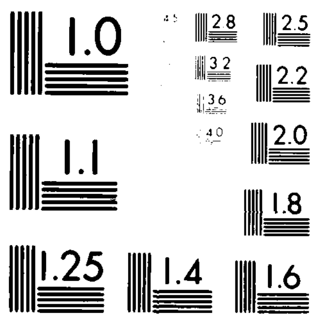

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DEPARTMENT OF THE ARMY
US ARMY INDUSTRIAL BASE ENGINEERING ACTIVITY
ROCK ISLAND, ILLINOIS 61299

25 JUN 1980

DRXIB-MT

SUBJECT: Manufacturing Methods and Technology Program
Project Summary Report (RCS DRCMT-302)

SEE DISTRIBUTION (Appendix II to Inclosure 1)

1. In compliance with AR 700-90, C1, dated 10 March 1977, the Industrial Base Engineering Activity (IBEA) has prepared the inclosed Project Summary Report.

2. This Project Summary Report is a compilation of MMT Summary Reports prepared by IBEA based on information submitted by DARCOM major subordinate commands and project managers. These projects represent a cross-section of the type of efforts that are being conducted under the Army's Manufacturing Methods and Technology Program. Persons who are interested in the details of a project should contact the project officer indicated at the conclusion of each individual report.

3. Additional copies of this report may be obtained by written request to the Defense Technical Information Center, ATTN: TSR-1, Cameron Station, Alexandria, VA, 22314.

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JAMES W. CARSTENS
Acting Director,
Industrial Base Engineering Activity

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A088 015	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) MANUFACTURING METHODS AND TECHNOLOGY. PROJECT SUMMARY REPORTS, A080751		5. TYPE OF REPORT & PERIOD COVERED Semi-Annual January—June 1980.
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Manufacturing Technology Division US Army Industrial Base Engineering Activity		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Industrial Base Engineering Activity ATTN: DRXIB-MT Rock Island, IL 61299		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (12) 246
11. CONTROLLING OFFICE NAME AND ADDRESS HQ, DARCOM, US Army Materiel Development & Readiness Command, ATTN: DRCMT, 5001 Eisenhower Ave., Alexandria, VA 22333		12. REPORT DATE June 1980
		13. NUMBER OF PAGES 247
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report)
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution unlimited.
Document for public release.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Distribution unlimited.
Document for public release.

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Manufacturing methods
Manufacturing technology
Technology transfer
MMT Program

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report contains summaries of 112 projects that were completed under the Army's Manufacturing Methods and Technology (MMT) Program. The MMT program was established to upgrade manufacturing facilities used for the production of Army materiel. The summaries highlight the accomplishments and benefits of the projects and the implementation actions underway or planned. Points of contact are also provided for those who are interested in obtaining additional information.

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INTRODUCTION

Background

The Manufacturing Methods and Technology (MMT) Program was established to upgrade manufacturing facilities used for the production of Army materiel, and as such, provides direct support to the Industrial Preparedness Program. The Manufacturing Methods and Technology Program consists of projects which provide engineering effort for the establishment of manufacturing processes, techniques, and equipment by the Government or private industry to provide for timely, reliable, economical, and high-quality quantity production means. The projects are intended to bridge the gap between demonstrated feasibility and full-scale production. The projects are normally broad based in application, are production oriented, and are expected to result in a practical process for production. The projects do not normally include the application of existing processes, techniques, or equipment to the manufacture of specific systems, components, or end items, nor do they apply to a specific weapon system development or a product improvement program.

MMT Program Participation

MMT Programs are prepared annually by DARCOM major subordinate commands. These programs strive for the timely establishment or improvement of the manufacturing processes, techniques, or equipment required to support current and projected programs.

Project proposals (Exhibits P-16) are submitted to the appropriate MMT Program Office. A list of offices is provided in Appendix I. Additional information concerning participation in the MMT Program can be obtained by contacting an office listed or by contacting Mr. James Carstens, AUTOVON 793-5113, or Commercial (309) 794-5113, Industrial Base Engineering Activity, Rock Island, IL 61299.

In anticipation of the lengthy DOD funding cycles, projects must be submitted in sufficient time for their review and appraisal prior to the release of funds at the beginning of each fiscal year. Participants in the program must describe manufacturing problems and proposed solutions in Exhibit P-16 formats (see AR 700-90, 4 August 1975, for instructions). Project manager offices should submit their proposals to the command that will have mission responsibility for the end item that is being developed.

Contents

This report contains summaries of 112 completed projects that were funded by the MMT Program. The summaries are prepared from Project Status Reports (RCS DRCMT-301) and Final Technical Reports submitted by organizations executing the MMT projects. The summaries highlight the accomplishments and benefits of the projects and the implementation actions under way or planned. Points of contact are also provided for those interested in obtaining additional information.

The MMT Program addresses the entire breadth of the Army production base and, therefore, involves many technical areas. For ease of referral, the project summaries are grouped into six technical areas. The technical areas are CAD/CAM, Electronics, Inspection and Test, Metals, Munitions, and Non-Metals.

The Summary Reports are prepared and published for the Office of Manufacturing Technology, DARCOM, by the Manufacturing Technology Division of the Army Industrial Base Engineering Activity, (IBEA) in compliance with AR 700-90, C1. The report was compiled and edited by Mr. Andrew Kource, Jr. and ably assisted by Ms Cheryl Taylor with the typing and graphics arrangements.

COMPUTER AIDED DESIGN/
COMPUTER AIDED MANUFACTURING
(CAD/CAM)

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 176 7103 and 177 7103 titled, "Improved Manufacturing of Blisk and Impeller Turbine Engine Compressor Components," were completed by the US Army Aviation Research and Development Command in August 1979 at a total cost of $740,000.

BACKGROUND

The T700-GE-700 turboshaft helicopter engine is the main powerplant for the Army in the 80's and beyond. Production qualified in early 1976, conventional, labor intensive methods were used to manufacture the blisk and impeller airfoils. Airfoils have complex shapes, high twist gradients, large camber and close spacing, and require precisely machined three dimensional contours. Trailing edges may be as thin as 0.006 inch, and the profile of leading edges must be aerodynamically acceptable. Operations on these components were performed at five widely separated locations thus creating high transportation and handling costs.

SUMMARY

The objective of this MMT program was to develop a manufacturing system for producing airfoils as integral features of blisks and impellers, see Figure 1.

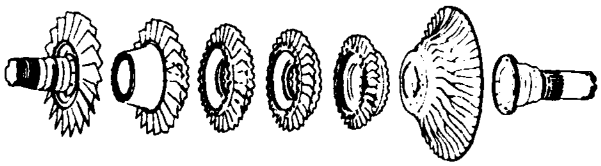


Figure 1 - Blisk and Impeller Components

The goal was to increase productivity to meet projected needs and at the same time, reduce costs. Three tasks were identified: (1) develop a multiaxis, multispindle numerical control milling technique to produce blisk and impeller airfoils, (2) develop finishing procedures to obtain the required airfoil surface finish and contour, and (3) select special equipment for inspection of the complete airfoil.

Task 1: A 4-spindle, 5-axis CNC airfoil milling machine was designed and a prototype constructed. Machining the blisk and impeller was a unique programming challenge. In addition to defining the cutter paths and angles necessary to machine airfoils having high twist angles and varying contours, the program had to prevent the inadvertant machining of adjacent airfoils. APT language was selected for blisks and HECTRAN was used for the impeller.

Task 2: Various ways were studied for finishing the airfoil surfaces. After tests with electrochemical and proven abrasive processes, a relatively new process, abrasive-flow machining (AFM) was chosen. Applying AFM required the development of the right media viscosity, the right combination of abrasive particles, and the correct pressure/temperature conditions to flow the abrasive media between the airfoils following the airflow path.

Task 3: An unusually efficient inspection process was developed. Both blisk and impeller airfoils are measured at literally hundreds of points to indicate such items as airfoil thickness, chord length, airfoil twist and length, airfoil contours, leading and trailing edge contours, surface roughness, and root blend radii.

The Blisk and Impeller Process Development Program has led to important gains in manufacturing capabilities. Combining these advanced processes into a complete airfoil manufacturing system resulted in major savings in time over conventional processes with a commensurate savings in labor costs.

BENEFITS

Manufacturing cost reductions of 60% per engine set lead to projected program savings of more than $60 million. In addition to dollar savings, design requirements are more uniformly met resulting in improved engine performance.

IMPLEMENTATION

Technology and production equipment developed under this program have been implemented at the GE T700 production facility at Hooksett, NH.

MORE INFORMATION

Additional information and a copy of the contractor's final technical report is available from Mr. Fred Reed, AVRADCOM, AV 693-1625 or Commercial (314) 263-1625.

Summary Report was prepared by J.H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 276 9679 titled, "MMT Numerical Control Lathe Language Evaluation" was completed by the US Army Communications Research and Development Command in December 1979 at a cost of $395,000.

BACKGROUND

At least eighteen major Numerical Control (NC) languages are available for workpiece programming of NC lathes. Each language has specific advantages, capabilities, limitations, and costs. The problem confronting a potential user is to match the capabilities of the NC languages with the forecasted workpiece programming workload within a given organization and minimize the workpiece programming time and cost. A prior MMT project, 272 9679, evaluated seven NC languages for workpiece programming of milling, drilling, and boring machines and machining centers.

SUMMARY

The objective of this effort was to conduct an unbiased comparison of the NC lathe programming systems, identify differences between the systems, and disseminate the results of the comparison. The selection of a candidate system was based on commercial availability, current support by a proponent, and active users (not necessarily just government agencies). A list of fifteen participants is presented in Table 1 along with the name of the system. A questionnaire was formulated, completed by the proponent of a candidate system, and the replies were analyzed. Each of the fifteen participating proponents were asked to submit copies of a programmer's manual. These manuals were evaluated and graded for adequacy of documentation and ease of use. A set of 33 patterns were distributed to the system proponents and they responded with a set of statements appropriate to each pattern. The fifteen systems were then characterized and the claimed technical capabilities were summarized covering:

a. A description of the system
b. Workpiece description capability
c. Special lathe routines or macros
d. Tool control procedures and technology of metal cutting

Ten benchmark or test parts were designed and each proponent was asked to program these parts and verify the tapes produced.

Serial Number	Name of Participant and Address	Name of System
1	Cincinnati Milacron, Inc., Machine Tool Group 4701 Marburg Avenue, Cincinnati, Ohio 45209	Cinturn II
2	Digital Systems Corporation 317 Monroeville Mall, Monroeville, PA 15146	QUICK-PATH
3	Encode, Inc. Perkins Way Dexter Industrial Green, Newburyport, MA 01950	Genesis
4	General Electric Co., Inf. Services Business Div. 401 N. Washington St., Rockville, MD 20850	GETURN
5	Ingersoll Milling Machine Company Rockford, Illinois 61101	Ingersoll Lathe Program
6	Manufacturing Data Systems, Inc. 4521 Plymouth Road, Ann Arbor, MI 48105	COMPACT II
7	Manufacturing Software & Services 6761 Bramble Ave., Cincinnati, Ohio 45227	TOOLPATH
8	McDonnell Douglas Automation Company P. O. Box 516, St. Louis, Missouri 63166	APT for lathes
9	Olivetti Corporation of America 500 Park Avenue, New York, New York 10022	GTL/T
10	Structural Dynamics Research Corporation 5729 Dragon Way, Cincinnati, Ohio 45227	APTURN
11	Threshold Technology, Inc. 1829 Underwood Boulevard, Delran, NJ 08075	VNC
12	United Computing Corporation 22500 S. Avalon Boulevard, Carson, CA 90745	UNIAPT
13	University Computing Company 1930 Hi Line Drive, Dallas, Texas 75247	UCCAPT
14	Weber N/C Systems 11611 West North Avenue, Milwaukee, WI 53226	PROMPT
15	Westinghouse Electric Corp., Industry Systems Div. 200 Beta Drive, Pittsburgh, PA 15238	WESTURN

Table 1 - List of Participants

The findings of this comparison study were presented in matrix format with footnotes and explanatory sections, and published in a technical report. A typical exercise was performed as an illustration, Figure 1, with documented assumptions using the results of this evaluation; total cost for workpiece programming is plotted for eight participants and five test parts.

BENEFITS

With the results of this evaluation, a potential user of a NC lathe language may make a more informed selection with an increase in productivity and/or lower costs. This project has demonstrated that the capabilities of language processors available to the general public exceed the capabilities currently in use by DOD components. The DOD performance, although monitored on a limited basis, did not compare favorably with the performance of the proponents.

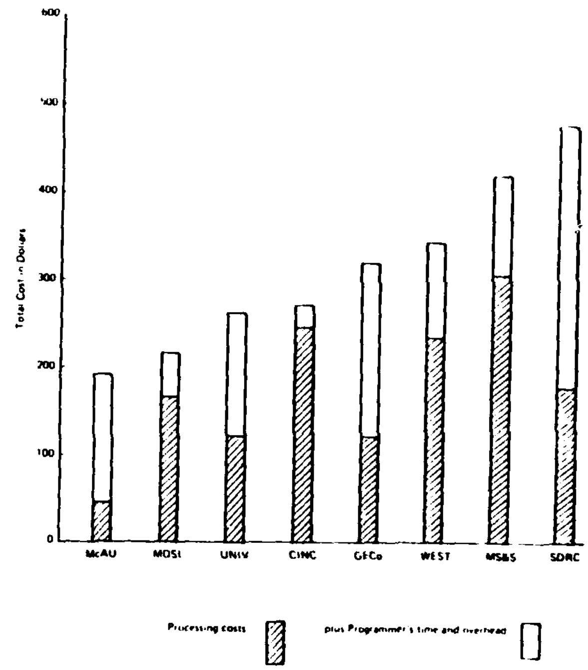


Figure 1 - Time Share Costs for Parts
1, 2, 6, 7, and 8

IMPLEMENTATION

Public announcement of the completion of the project was made on 5 December 1979 at a press conference held in Washington, DC. The results of this project have been published through a DIPEC workshop, the MTAG 1979 conference, and at least seven trade magazines or periodicals. The NC Society is interested in furthering the implementation of the results of this project. They have arranged to conduct Seminars (first held 27-28 Feb 80) and distribute copies of the final technical report. The NC Society is also conducting a survey to estimate cost savings or productivity increases that have been attributed to this project or the prior effort.

MORE INFORMATION

The project officer for this effort is Mr. David Ruppe, US Army Communications Research and Development Command, ATTN: DRDCO-AM, Ft. Monmouth, NJ 07703, AV 995-4251 or Commercial (201) 544-4251. For additional information, a technical report is available titled, "Numerical Control Lathe Language Study", Authors P.D. Senkiew, J.J. Childs, J. Harrington, D.K. Ruppe, November 1979. Defense Technical Information Center number is ADA-081683.

Summary Report was prepared by Stephen A. McGlone, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 374 3091 titled, "Methods of Automatically Affixing Cables to Electrical Connectors" was completed in January 1976 by the US Army Missile Command at a cost of $156,000.

BACKGROUND

Cables are one of the weakest links in the chain of a weapon system. The current methods of fastening cables to connectors are costly and/or inadequate. As an example, of the 37 cables on one fire unit, 21 cables had thirty-eight failures of which thirteen failures were due to connector part problems and the remaining failures were due to human errors. Additionally, the connector, shells, pins, and conductors are frequently overstressed and/or degraded during the manufacturing process.

SUMMARY

The objective of this project was to develop an automatic computer controlled manufacturing process for affixing electrical connectors to cables to eliminate the possibility of human errors, and thereby, increase the reliability of the cables. The approach followed three phases. The first was in information gathering survey of industry harness environment. The second phase consisted of the evaluation and selection of fundamental concepts and techniques that could be used for the mechanized processing of wires, contacts, and connectors into harness configurations. The third phase concentrated on the conceptual design, see Figure 1, of a prototype fabrication facility for preparation of required wire elements and processing of an automated cable-connector interconnection, assembly, and verification test for a harness configuration. A two-month program extension was used to evaluate four overscope problems: (a) fabrication of a standard compatible harness using a new concept of presizing and terminating the wires before assembly, (b) study of SAFEGUARD equipment for design features that may be usable on the program concept, (c) further study on methods of stripping difficult insulations and braiding, and (d) further study on soldering of terminals.

BENEFITS

A computer controlled manufacturing process for affixing cables to electrical connectors would eliminate the possibility of human error and would be applicable to all using departments of the Government as well as industry.

The increase in cable reliability would improve the readiness of using systems while reducing the manufacturing cost, increasing energy savings, reducing spare parts requirements, and their associated handling and shipping costs.

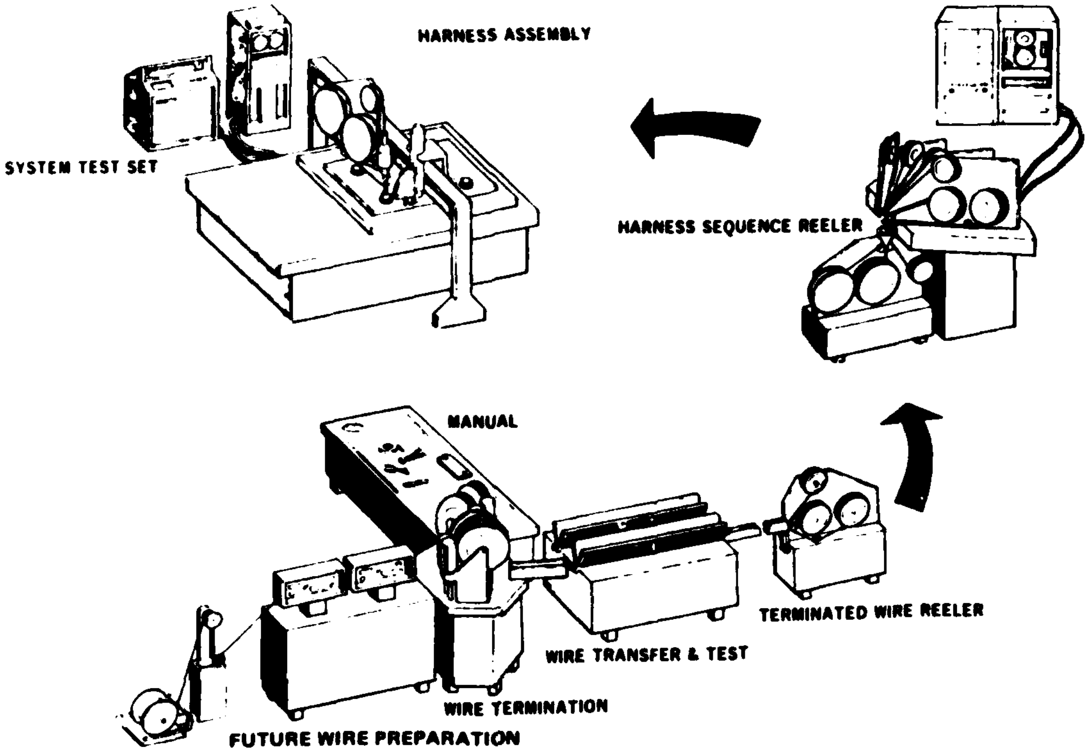


Figure 1 - System Concepts

IMPLEMENTATION

The results of this project were applied to project 376 3091.

MORE INFORMATION

Additional information on this project is available from Mr. Richard A. Kotler, MICOM, AV 746-3777 or Commercial (205) 876-3777.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 376 3091 titled, "Methods of Automatically Affixing Cables to Electrical Connectors" was completed in August 1977 by the US Army Missile Command at a cost of $250,000.

BACKGROUND

The current methods of fastening cables to connectors have resulted in cable failures due to connector part problems and to human errors. Human errors account for the majority of failures resulting from incorrectly wired cables, incorrect shield terminations, improper potting compound, improper torque on backshells, excess solder left in the connector and overstressing of the connector, shells, pins, and conductors during the manufacturing process. Prior effort in this area was performed under project 374 3091 titled, "Methods of Automatically Affixing Cables to Electrical Connectors" of which this project is a continuation.

SUMMARY

The objective of this project was to establish an automatic computer controlled manufacturing process for affixing electrical connectors to cables. Additional minor objectives were to demonstrate the system to Government and Industry and provide documentation on the system so that it could be obtained and applied. Analysis of harness requirements resulted in selecting a compatible environmental connector with removable pins that were first crimped to standard 20, 22, or 24 guage wires and then snapped into the connector from the rear through a resilient seal. A conceptual approach was developed for the presizing, termination, and storage of wires in a sequenced order on a reel. In this approach, the reels are held in storage until a harness assembly is scheduled. When assembly is desired, the reel is loaded onto a connector insertion machine. The wires are dispensed in such a manner that the terminal end is grasped and inserted into a connector body positioned in a vertical direction on the X-Y table tooling board. The wire is then laid into guides on the X-Y table and the second end is inserted into another connector. This procedure is repeated by means of a programmed controller until all wires are inserted and positioned on the tooling board. The harness is then manually dressed, tied, and sent to test.

At the final report of this project, the Mechanical Assembly mechanism was 80% completed and the Control System Fabrication had been started. All mechanism checks made had resulted in design verification. Drive and control system subassemblies are being checked out as per design requirements.

BENEFITS

A computer controlled manufacturing process for affixing cables to electrical connectors when completed would eliminate the possibility of human error and would be applicable to all using departments of the Government as well as industry. The increase in cable reliability would improve the readiness of using systems while reducing the manufacturing costs, increasing energy savings, and reducing spare parts requirements and their associated handling and shipping costs.

IMPLEMENTATION

This effort will be continued under project 377 3091.

MORE INFORMATION

Additional information on this project is available from Mr. Richard A. Kotler, MICOM, AV 746-3777 or Commercial (205) 876-3777.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 37T 3091 titled, "The Application of Computer Controlled Manufacturing Process to Methods for Affixing Electrical Connectors to Cables (CAM)" was completed by the US Army Missile Command in February 1978 at a cost of $150,000.

BACKGROUND

The current methods of fastening cables to connectors have resulted in cable failures due to connector part problems and human errors. Human errors account for the majority of failures as a result of incorrectly wired cables, incorrect shield terminations, improper potting compound, improper torque on backshells, excess solder left in the connector and overstressing of the connector, shells, pins, and conductors during the manufacturing process. Prior efforts in this area were performed under projects 374 3091 and 376 3091 titled, "Methods of Automatically Affixing Cables to Electrical Connectors" of which this project is a continuation.

SUMMARY

The objective of this project was to establish an automatic computer controlled manufacturing process for affixing electrical connectors to cables. This will eliminate the possibility of human errors in manufacturing and, therefore, increase the reliability of the cables. Additional minor objectives were to demonstrate the system to Government and Industry and provide documentation of the system so that it can be obtained and applied. During this project, the reel redesign for storage of wires in a sequenced order, the tooling board rework, see Figure 1, and the inserter pneumatics were completed. Also, the control system was installed, torque motors were reworked to reduce loading, reel-to-reel sequencer mechanical parts were completed, harness wire sample sets were selected for reeling, the microprocessor was received and checked out, the X-Y table contract was let, and the harness tying study was completed. In addition, the transfer conveyer was being designed, channel/tape storage system upgrading was in process, and the Harness Design Handbook and Machine Process Handbook were in process of being developed.

The final report of this project stated the mechanical assembly was 85% complete and the control system fabrication was 40% complete.

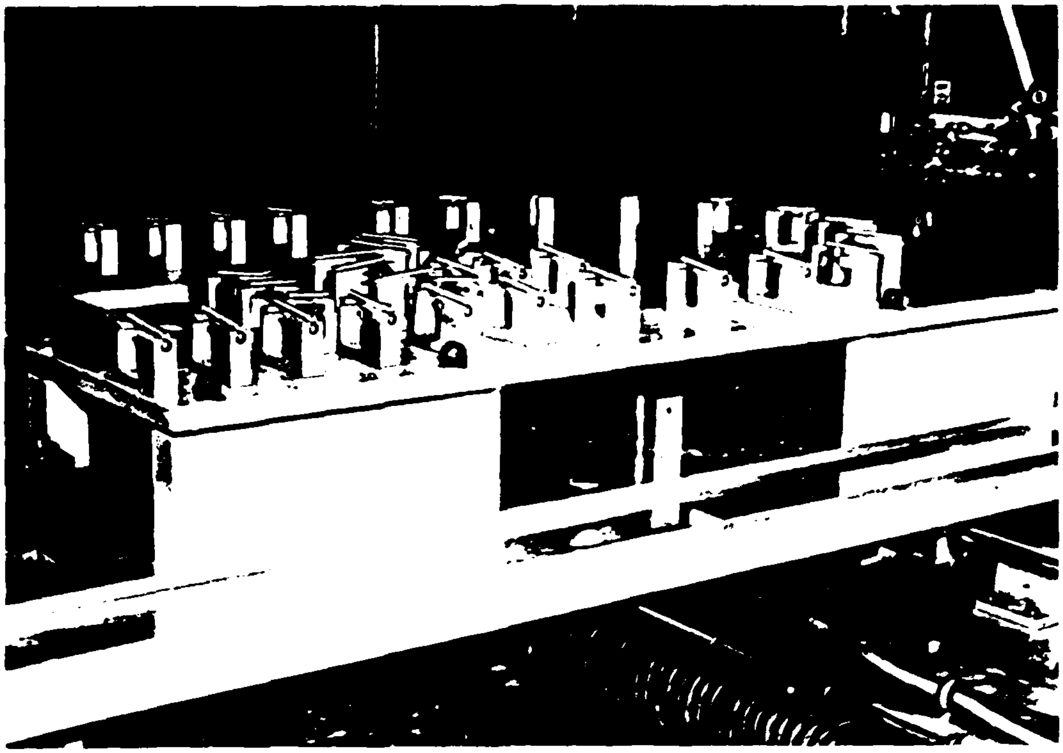


Figure 1 - Tooling Board

BENEFITS

Increased cable reliability would improve the readiness of systems employing cables, while reducing the manufacturing costs, reducing energy consumption, and reducing spare parts requirements and their associated handling and shipping costs.

IMPLEMENTATION

This effort was continued under project 377 3091.

MORE INFORMATION

Additional information on this project is available from Mr. Richard A. Kotler, MICOM, AV 746-3777 or Commercial (205) 876-3777.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 377 3091 titled, "The Application of Computer Controlled Manufacturing Process to Methods for Affixing Electrical Connectors to Cables (CAM)" was completed by the US Army Missile Command in February 1980 at a cost of $140,000.

BACKGROUND

The current methods of fastening cables to connectors have resulted in cable failures due to connector part problems and human errors. Human errors account for the majority of failures as a result of incorrectly wired cables, incorrect shield terminations, improper potting compound, improper torque on backshells, and excess solder left in the connector, shells, pins, and conductors during the manufacturing process. Prior efforts in this area were performed under projects 374 3091 and 376 3091 titled, "Methods of Automatically Affixing Cables to Electrical Connectors" and project 37T 3091 titled, "The Application of Computer Controlled Manufacturing Process to Methods for Affixing Electrical Connectors to Cables (CAM)" of which this project is a continuation.

SUMMARY

The objective of this project was to establish an automatic computer controlled manufacturing process for affixing electrical connectors to cables. This would eliminate the possibility of human errors in manufacturing and therefore, increase the reliability of the cables. Additional minor objectives were to demonstrate the system to Government and Industry and provide documentation on the system so that it can be obtained and applied. This project was the fourth phase of a four phase effort. Prior projects established methods and equipment for attaching connector pins to wires. This project utilized a computer controlled wire routing machine, Figure 1, to search for a specific wire, having pre-attached connector pins, grasp it, and insert it into a multi-pin connector. The wire was then routed over a harness layout board and the pin on the other end of the wire was inserted into another connector. All items were successfully demonstrated.

BENEFITS

Increased cable reliability will improve the readiness of systems employing cables, while reducing the manufacturing costs, energy consumption, and spare parts requirement along with associated handling and shipping costs.

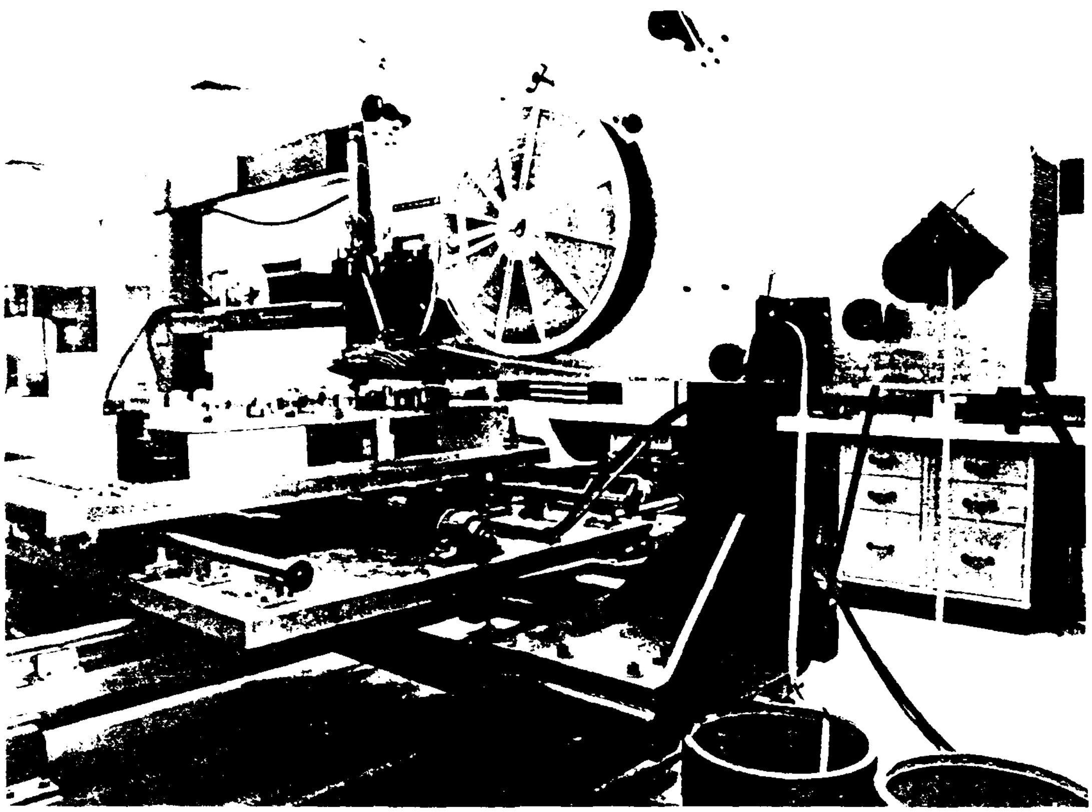


Figure 1 - Harness Assembly Machine

IMPLEMENTATION

Project results have been implemented as a mechanized laboratory facility with full scale engineering prototype machines that have been used to make experimental runs and demonstrations. Sample harnesses have been successfully fabricated and the concept has been verified as developed. The total complement of equipment demonstrated is currently available on a no-cost loan basis from the Government for additional development or for production implementation.

MORE INFORMATION

Additional information on this project is available from Mr. Richard A. [illegible]tler, MICOM, AV 746-3777 or Commercial (205) 876-3777.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING TECHNOLOGY DIVISION

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 378 3268 titled, "Automatic Control of Plating (CAM)" was completed by the US Army Missile Command in February 1980 at a cost of $412,433.

BACKGROUND

Plating lines for printed wire boards (PWB) have an extremely large number of variables which influence printed circuit board quality. These variables include plating voltages, current densities, time in solutions, solution Ph, solution composition, and cleaning and rinsing time between baths. The degree of complexity is such that manual control methods cannot maintain the tight tolerances that are required for the highest quality results. If any variable drifts out of relatively narrow bounds impaired quality results.

This project was undertaken to establish an automatic sensing and control system applicable to virtually all critical solutions in a PWB plating line.

SUMMARY

The objective of this project was to improve printed wiring board yield and reliability by implementing a computer controlled process of automatic solution monitoring and control system. In addition, the developed monitoring and control technology is intended to be sufficiently versatile so as to apply to virtually any solution used for PWB processing.

This project approach consisted of four tasks. The first task was a survey of the plating industry to determine present state-of-the-art and development status of process solution monitoring and control. The sec task was a survey of analytical equipments, sensors, and associated systems suitable for incorporation into a computerized solution monitoring system. The third task involved specifying the procurement and assembly of the appropriate sensing and control equipment. The fourth task established an inventory control system capable of automatically computing and recording materials used, materials in stock and materials reordering, and signaling the end of processing solutions useful life.

As a result of these tasks, an analytical sensing subsystem has been selected which will use a computerized polarographic analyzer for the simultaneous determination of two or more constituents in each processing solution. Using this approach, all of the critical solutions in a PWB can be monitored with a single sensing system, rather than a conglomeration of multiple unrelated sensors. In order to accomplish the multiple sensoring of critical solutions, specified analytical control procedures were developed fcr each solution in a typical PWB plating line. This was achieved by first defining for each solution which constituents would provide a reliable index as to the status of a solution chemistry, see Table 1.

	Electrode	Supporting Electrolyte	Dilution	Scan Range (V)	Peak (V)
Conditioner					
Alkalinity	HMDE	0.1M KNO_3	1:1000	0.35 to -0.4	0.1
Pre-etch					
Copper	HMDE	PO_4-Citrate buffer (pH7)	1:5000	0.0 to -1.5	-0.14
Hydrogen peroxide	HMDE	PO_4-Citrate buffer (pH7)	1:5000	0.0 to -1.5	-0.95
Catalyst					
Paladium	DME	1M Pyridine - 1M KCL	1:10	-0.1 to -0.85	-0.37
Stannous tin	DME	Acetate buffer (pH4)	1:1000	0.0 to -0.75	-0.54
Accelerator					
Stannic tin	DME	4M NH_4CL - 1M HCL		-0.15 to -0.9	-0.57
Electroless copper					
Copper	DME	0.05M EDTA - 0.5M N_aOH	1:1000	-0.3 to -1.8	-0.54
Formaldehyde	DME	0.05M EDTA - 0.5M N_aOH	1:1000	-0.3 to -1.8	-1.71
Sodium hydroxide	DME	0.1M KNO_3	1:1000	0.35 to -0.4	0.1
Copper Electroplate					
Copper	HMDE	0.1M KNO_3	1:1000	0.2 to -2.0	0.0
Sulfuric acid	HMDE	0.1M KNO_3	1:1000	0.2 to -2.0	-1.4
Solder electroplate					
Lead	DME	Acetate buffer (pH4)	1:1000	0.0 to -0.75	-0.43
Stannous tin	DME	Acetate buffer (pH4)	1:1000	0.0 to -0.75	-0.54
Nickel electroplate					
Chloride	DME	0.1M KNO_3-100g/L Mannitol	1:1000	0.4 to -1.8	0.3
Nickel	DME	0.1M KNO_3-100g/L Mannitol	1:1000	0.4 to -1.8	-1.05
Boric acid	DME	0.1M KNO_3-100g/L Mannitol	1:1000	0.4 to -1.8	-1.6

Table 1 - Analytical Control Procedures-
Differential Pulse Polarography

A computer control system was identified which consists of two distinct parts: a microprocessor-controller for control of all input/output functions and a monitor/programmer computer for software development, system monitoring, and data processing. The controller is an 8080 microprocessor-based instrument with the critical process control algorithms in nonvolatile memory for maximum convenience and security. The equipment is modular in configuration and can be readily expanded to control an entire plating shop.

The monitor/programmer computer is a Datapoint #1802 Dispersed Processor equipped with dual floppy disks (1 megabyte storage) and 64K RAM memory. Polarographic analysis data will pass from the controller to the Datapoint where it will be stored in a disk file for future reference and retrieval. The Datapoint will also monitor all phases of the system during operation.

BENEFITS

This project acquired computer-aided sensing and control equipment and established an inventory control system which will be used to improve quality and productivity in PWB processing. These acquisitions will be assembled and used in a small automatic PWB plating line and also in a production environment under project 379 3268.

IMPLEMENTATION

This effort will be continued under project 379 3268.

MORE INFORMATION

Additional information on this project may be obtained by contacting Mr. Loyd L. Woodham, MICOM, AV 746-1572 or Commercial (205) 876-1572.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 574 4255 titled, "Production Control of Acceleration Sensing Devices (CAM Related)" was completed in August 1975 by the US Army Armament Command at a cost of $50,000.

BACKGROUND

The production control of mechanical acceleration sensing devices for conventional ammunition fuzes was empirical and consisted of functional testing of completed assemblies. This approach resulted in production delays and a high percentage of rejects and scrap when components would fail to function as a complete unit.

The safety and arming device is a major fuze subassembly. The device senses acceleration through the use of a spring-mass system whose operation, at specified acceleration levels for set-back and spin, controls the arming of the fuze. The need for an in-process inspection of a spring-mass system of a fuze within the range of low and high acceleration levels is the functional requirement to which this project is addressed.

SUMMARY

The objective of this project was to establish methods for improving the process control of fuze acceleration sensing devices.

A review of current production control methods and techniques was performed. Then specific equipment and concepts were analyzed. A concept was developed to link a centrifuge test with the spring winding equipment to achieve an improvement in process control. This concept proposed feeding the centrifuge test data into a minicomputer which would analyze the data and then adjust the spring winder's controls. The concept developed is illustrated in Figure 1.

The arming level was determined primarily by the load characteristics of the spring in the spring-mass system. For example, a method of automatically adjusting the compression spring was formulated by calculating the required change in free length and directing the physical adjustment of the spring winder controls. A batch manufacturing approach was preferred because of stress relief and plating operations performed after the music wire spring was wound.

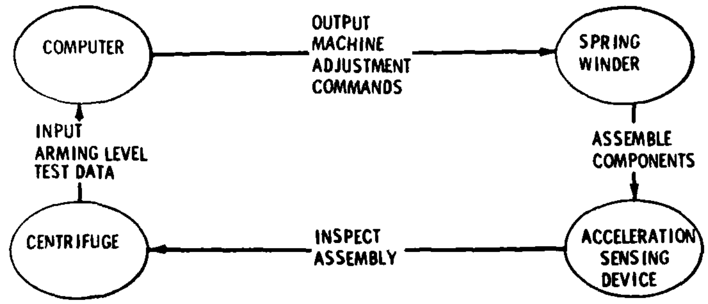


Figure 1 - Work Flow For Batch Manufacturing Process Control of Spring Winder

Recommendations were made for the fabrication of prototype equipment to validate the results of this concept study. The prototype equipment could consist of a 100% fully automatic load tester for springs, and a minicomputer directed spring winder system.

BENEFITS

A benefit realized from this effort is the definition of a concept for methods improvement of the process control of spring-mass components. The analysis of the spring manufacturing process also showed other equipment to improve the process control of fuze springs, at a minimum cost. Such equipment includes on-machine gauging equipment, spring separators, and spring load tester. To date, these methods improvements have not resulted in savings in the procurement of fuzes because they have not been implemented.

IMPLEMENTATION

The results of this effort were to be implemented by a follow-on MMT project. However, that project has not been funded at this time due to the low production requirements of fuzes.

MORE INFORMATION

Additional information on this project is available in a technical report titled, "Production Control of Acceleration Sensing Devices CAM Related" dated August 1976, DDC# AD-A-029455. The project officer is Mr. Tom McKimm, US Army Armament Research and Development Command, Dover, NJ, AV 880-2644 or Commercial (201) 328-2644.

Summary Report was prepared by Stephen A. McGlone, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 576 4280 titled, "M577 Fuzes-Automatic Process Control Prototype Equipment" was completed by the US Army Armament Research and Development Command in January 1980 at a cost of $208,000.

BACKGROUND

Prior to this MMT effort, the methods used to perform process control of the M577 fuze were production bottlenecks. Process controlling involved three operations: zero setting three module assemblies, poising the balance wheel assembly, and adjustment of the timer beat rate. Methods utilized to accomplish these tasks were difficult and time consuming. The zero set operation is particularly critical; however, adjustment was subjected to visual judgement. This program identified automation techniques and developed equipment specifications required for these operations.

SUMMARY

The objective of this program was to verify that automation could be applied to the operations of zero setting, poising, and timer beat rate adjustment. Engineering specifications including design details and drawings were developed for fabricating automated equipment to perform these operations.

Two engineering studies were conducted. Hamilton Technical, Inc. investigated and verified that automation along with computer technology could be applied to the zero setting operation. Six major areas of the fuze were investigated: (1) Locating the 0-0-0 position on the counter assembly, (2) removing the backlash from the gear train in the fuze, (3) meshing the internal tooth gear in the number three wheel with the setting gear drive plate, (4) assembling and crimping the counter housing skirt without disturbing the zero set, (5) installing the counter weight without disturbing the zero set, and (6) electronic computer control system. The results of the study justified the construction of a prototype machine.

The second study, conducted by Bulova S&I Corp., was to verify that automation along with computer technology could be applied to the adjustment of the timer beat rate and to the poising operations. The study proved that the timer regulation could be accomplished automatically utilizing computer controlled and ultrasonic welding techniques. Laser machining was demonstrated for poising the balance wheel. This method was chosen over mechanical material removal because the laser beam acts instantaneously, never needs sharpening, and can remove material without stopping the rotating balance wheel. For both operations, fabrication of prototype machinery was considered justified.

BENEFITS

This project proved the feasibility of automating the process controlling operations for the M577 fuze. Engineering specifications for the fabrication of three prototype machines were developed.

IMPLEMENTATION

The concepts developed and proven under this project will be developed into prototype production machines under a follow-on project, MMT 577 4280.

MORE INFORMATION

For additional information, see MMT project 577 4280 or contact Mr. T. McKimm, US Army Armament Research and Development Command, AV 880-2644 or Commercial (201) 328-2644.

Summary Report was prepared by J.H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 577 4280 titled, "M577 Fuzes-Automatic Process Control Prototype Equipment" was completed by the US Army Armament Research and Development Command in January 1980 at a cost of $900,000.

BACKGROUND

The methods used in process control for the M577 Fuze were considered production bottlenecks. A prior project, MMT 576 4280, proved that automation techniques could be utilized to improve production processes. The FY76 project developed engineering specifications for automated machines. This project fabricated and provided "prove out" of prototype equipment.

SUMMARY

The purpose of this project was to fabricate automatic process control prototype equipment for the M577 Fuze. Three operations were involved: zero setting the three module assemblies, poising the balance wheel assembly, and adjusting the time beat rate.

a. Automatic Zero Set Machine - A machine was fabricated and tested. Certain M577 Fuze parts were modified to accommodate the machine and acceptance testing was conducted. Although the resulting ballistics tests were satisfactory, it was found that some design changes were needed to increase machine accuracy and more ultrasonic staking research was necessary to make the machine usable on a production line.

b. Automatic Poising Machine - A machine was fabricated, tested, and accepted for production. The machine was capable of automatically balancing 300-320 wheels per hour.

c. Automatic Regulation Machine - In order to automate adjustment of the timer beat rate, certain components of the M577 Fuze had to be modified. These fuze parts were manufactured and assembled and ballistics tests were conducted. During this testing phase, work on the automatic regulation machine continued. Upon completion, acceptance testing was conducted. Both the newly designed fuze components and the prototype equipment proved successful. The machine was capable of automatically regulating 190-200 timers per hour, see Figure 1.

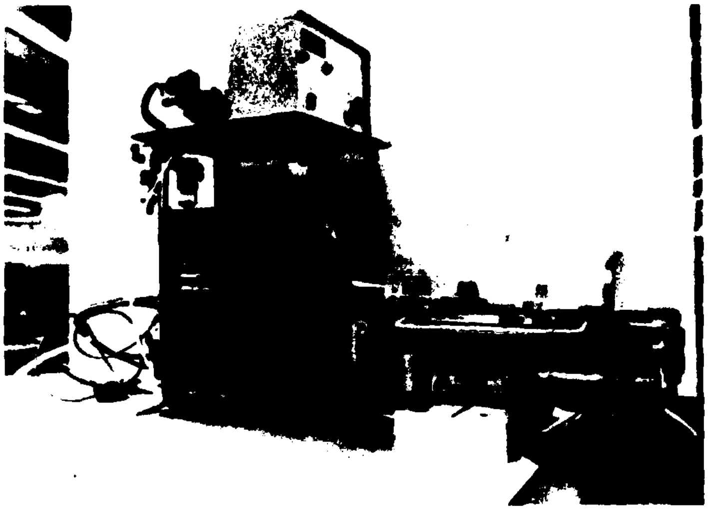


Figure 1 - Automatic Regulation Machine

BENEFITS

a. The automatic zero set machine has provided benefits in subassembly operation; however, it is too complex for direct implementation into production.

b. The automatic poising machine will allow 100% corrective balancing of the timer balance wheel assembly.

c. The automatic regulation machine will improve product consistency and reliability. Also, the skill level required for timer assembly has been reduced.

IMPLEMENTATION

a. The automatic zero set machine was not released for production.

b. The automatic poising prototype machine, along with one additional similar machine, was furnished to a contractor for M577 Fuze production.

c. The automatic regulation prototype machine, along with two additional machines, were furnished to contractors for M577 production.

MORE INFORMATION

Additional information is available from Mr. T. McKimm, US Army Armament Research and Development Command, AV 880-2644 or Commerical (201) 328-2644.

Summary Report was prepared by J.H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 576 4456 titled, "Computerized Materials Property Data Information System" was completed by the US Army Armament Research and Development Command in January 1979 at a cost of $100,000.

BACKGROUND

In the manufacture of military hardware, materials, and material processing are major elements of the total cost. The present methods of materials evaluations are conducted manually and are therefore time consuming. Manufacturing would be enhanced if material properties data were stored on computers and were made accessible by various users. This type of computerized material property and processibility data could have online access to support Army production engineering functions such as value engineering, product improvement, least-cost design, process improvement, and procurement.

SUMMARY

The objective of this project was to develop a DARCOM computerized material property data retrieval system to enable remote, on-line access to technical data for polymers (plastics, composites, and rubbers), metals, and ceramics, in support of engineering, manufacturing, and procurement functions.

To achieve this objective, the development of a new data management system was initiated which included three main areas of investigation. The first investigation considered writing a new program in scientific FORTRAN language. The second consideration investigated the modification of an existing Government owned program. The third investigation considered the modification or purchase of a new data base management system structured for material selection. After extensive considerations, the latter alternative approach was selected. The access modes to computerized data are highly dependent on the sophistication of the engineer/user in regard to design analysis, material technology, and computer technology. In view of this, the system selected provided capability for varied user background. A schematic, Figure 1, illustrates the generalized data retrieval concept utilized in this project. A data management system software package, which was written for IBM computers, was acquired and converted compatible with the Army's CDC 6000 series computers. Although

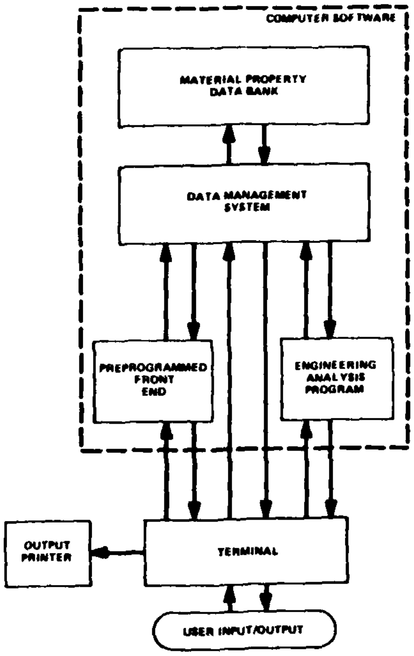


Figure 1 - Data Retrieval Concept

the conversion of the data management system to CDC was successfully completed, the overall project objectives were not achieved due to curtailment of funds.

BENEFITS

The only benefit achieved was the acquisition of a data base management system structured for material selection and the conversion of the system to the CDC 6000 series.

IMPLEMENTATION

Action is currently being taken to utilize the data management system for other material data projects as funding is made available.

MORE INFORMATION

Additional information may be obtained by contacting Mr. H.E. Pebly, ARRADCOM, AV 880-4222 or Commerical (201) 328-4222.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 575 6558 titled, "Adaptation of Automated Fuze Regulation" was completed by the US Army Armament Research and Development Command in January 1980 at a cost of $315,000.

BACKGROUND

The time movement of a fuze, based on the same principle used in clocks, utilizes a mainspring to provide driving power to the mechanism with its running speed controlled by the escapement machanism frequency. All movements must be regulated to a predetermined frequency in order to provide accurate timing. Fuze movements must be regulated and checked at a given spin level to assure accurate time under actual ballistic spin environments. When accomplished manually, regulation is the most time consuming and costly operation of fuze manufacture and has always been a bottleneck. Regulation adjustment is performed on a trial and error basis and requires a high degree of skill. In as much as the operation has always been troublesome and time consuming, it must utilize a large number of operators in order to keep pace with production line rates.

A prototype computerized automatic dynamic/static regulation machine was developed under project 569 6202. It consisted of one computer, a servo control, and three spin stations. The system performed automatic regulation adjustment to the fuze clock under either static or simulated spin conditions.

The overall objective of this effort was to fabricate and install a production model of the automatic regulation equipment at a current M564/M565 producer's facility for on-site operation and evaluation using production components.

Under the FY74 project, a contract was awarded to Bulova to build one computerized control station and two spin stations and to assemble and test the automatic regulation equipment, see Figure 1. Automatic chucks were provided by the C. N. Wood Co. Results were highly satisfactory as the equipment performed movement regulation properly without mishap or breakdown after running three workdays. The equipment was shipped to Westclox Division, General Time, where it was installed and preliminary testing accomplished.

This follow-on project, MMT 575 6558, was approved to perform the detailed testing of the equipment. In addition, it was devoted to completing the equipment and preparing technical data.

Figure 1 - Early models of computerized control station and two spin stations

SUMMARY

Two hundred eight fuzes were selected from computerized regulated lots and 240 fuzes from standard production lots for ballistic testing. The fuzes were fired from 105MM and 155MM Howitzers. Some differences were noted between fuzes that were regulated differently. Although the Government was satisfied that there was no statistical difference between the two methods, Westclox thought additional ballistic testing was necessary to more definitely establish the interchangeability of the automatic and conventional equipment. Interchangeability was important in the event both types of equipment were used simultaneously. The products of each type must be compatible for use in the same production lot of fuzes.

BENEFITS

The computer controlled automatic regulation machines have the potential of reducing the number of M564 production operations by 50%. In addition, the manual machines currently being used have not been manufactured for 15 years.

IMPLEMENTATION

The automatic equipment is currently not being used. Future utilization is contingent upon M564/M565 requirements and a decision on the need for additional testing.

MORE INFORMATION

Additional information on this program is available from Mr. Tom McKimm, US Army Armament Research and Development Command, AV 880-3265 or Commercial (201) 328-3265.

Summary Report was prepared by J.H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 576 6716 titled, "Development of Math Models of Forming Operations for Current/Future Artillery Metal Parts Designs" was completed by the US Army Armament Research and Development Command in June 1978 at a cost of $250,000.

BACKGROUND

There was a recognized need for more coordination between artillery metal parts manufacturers and designers. It was determined that a computer diagnostical tool was needed to provide commonality between various types of plant tooling, to reduce the engineering time consumed in tech data preparation, to predict the failure of metal parts during forming operations, and to minimize tool wear. Prior effort in this area was accomplished under project 573 6550 titled, "Engineering in Support of Artillery Metal Parts Modernization Program."

SUMMARY

The objective of this project was to determine the optimum combination of process variables for defect free nosing of shell by means of computer modeling. The objective was accomplished through the development of a comprehensive computer program named NOSING, which is capable of predicting the load-stroke curve, the optimum preform design, buckling (if it occurs), and the number of hits required to complete this nosing operation.

Small scale experiments, equivalent to the cold nosing of 105mm shells, were conducted in which twelve nine-inch long seamless tubing with 4.2500 inch OD and .4375 inch wall thickness were prepared for cold-drawn mild steel (AISI 1018). The nosing die was machined from a 10-inch diameter by 11-inch long piece of annealed H-12 tool steel. The shape of the die cavity was machined to correspond to the nosed portion of a 105mm M1 shell. After the appropriate sub-operations, (i.e., descaling, chamfering of corners, heat-treatment of die, etc.) were performed, the specimens were pushed to various depths into the die, which was coated on the inner surface with MoS_2 spray prior to nosing. Several of the specimens showed slight buckling at the nose base near the end of the stroke. Nosing loads and strokes were recorded from the instrumented 700-ton HPM press. At the end of nosing, the specimens were inspected and the diameter at the nose tip and the final length of the specimen were measured. Test data obtained for wall thickness, elongation, and load-stroke curve showed good correlations with predicted values. Slight bucklings were observed in several specimens, which were also predicted by the computer program, NOSING. These experiments validated that the computer program, NOSING, is capable of predicting local buckling due to cold nosing and the program is also capable of predicting the load-stroke curve in cold nosing with good accuracy.

BENEFITS

Cost savings will be realized through reduction in time required for preparation of technical data packages for equipment procurement and set-up which will also improve readiness. Energy savings will result from less power needed for forming, less scrap, and improved tool life.

IMPLEMENTATION

The computer program NOSING has been loaded into the ARRADCOM computer system. The results of this project are applicable to any shell production line which has a nosing operation for metal forming.

MORE INFORMATION

Additional information on this project may be obtained by contacting Fee M. Lee, ARRADCOM, AV 880-6345 or Commercial (201) 328-6345.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 670 7110 titled, "Feasibility of Computerized Manufacturing" was completed by the US Army Armament Research and Development Command in December 1975 at a cost of $800,000.

BACKGROUND

During the late 1960's one of the most outstanding advances in manufacturing technology was Direct Numerical Control (DNC). In 1970, Rock Island Arsenal (RIA) purchased a Sundstrand Omnicontrol DNC system. This system integrated five machine tools including three machining centers, a lathe, and a turret lathe with a minicomputer.

SUMMARY

The objective of this project was to develop, document, and implement software required to augment the operational Sundstrand Omnicontrol DNC system at RIA to form a Computer Aided Manufacturing (CAM) System. (A CAM system is a manufacturing system in which the planning, making, and controlling functions are managed either totally, or to a great extent, by a computer). The specific tasks to be added or addressed included: job shop scheduling in the background and/or interactive mode, sequenced machine group work loading, machine tool operation monitoring and utilization reporting, current operation file maintenance and operation history report generation, utilization of the DNC computer as a data transmission terminal to a remote computer for APT programming, and utilization of the existing Executive System to permit the DNC computer to handle all of the above components. IIT Research Institute (IITRI) was awarded the contract for this effort. In augmenting the existing DNC system with CAM capabilities, IITRI designed and developed four major computer programs that operated on the DNC computer. A simple block diagram depicting the DNC/CAM system is provided in Figure 1. Two of these programs strengthened the CAM planning function; one, a Scheduler does pre-planning and sets start and completion dates for each operation of every job in the system. The other program uses real-life status information about materials, tools, part programs, and available machine tool capacity to establish a sequence or order in which the operations should be processed on each machine tool.

CAM control is provided by the other two of the four programs; one provides data on what each machine tool is doing or has accomplished. The second keeps track of the performance history of every operation done on each of the DNC machines making it possible to compare what actually happened with what was planned.

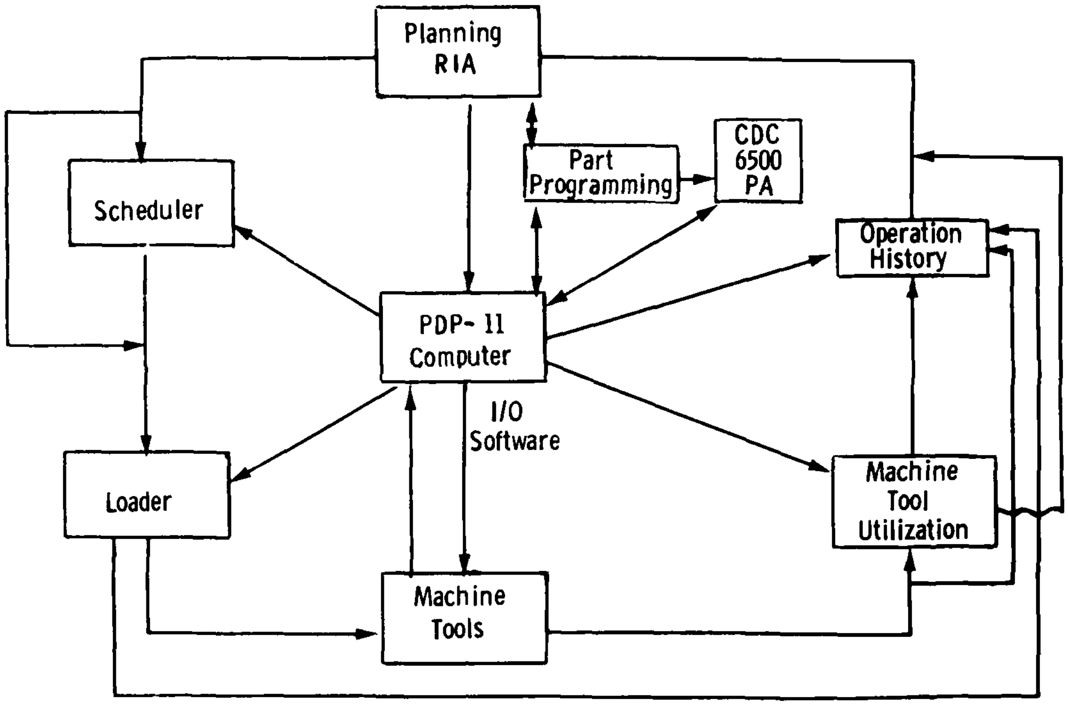


Figure 1 - RIA DNC/CAM System Overview Schematic

BENEFITS

The development/installation of the RIA DNC/CAM System proved the technical and economic feasibility of this type of approach.

IMPLEMENTATION

The software developed under this project was debugged and used in production at Rock Island Arsenal, Illinois.

MORE INFORMATION

A technical report titled, "Computer Aided Manufacturing System" published by IIT Research Institute, Contract No. DAAF01-73-0128 is available. Contact Mr. John Fox, Rock Island Arsenal, AV 793-6322 or Commerical (309) 794-6322.

Summary Report was prepared by J.H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 672 7220 titled, "MMT Application and Utilization of Mini-Computers to Direct Numerical Control for General Purpose Machine Tools" was completed by the US Army Armament Command in June 1975 at a cost of $140,000.

BACKGROUND

Part programming for 3-axis numerical control machine tools was done using a time sharing system over long distance telephone lines. The time share expense and labor to prepare part programs justified consideration of a mini-computer stand-alone tape preparation system. This project was established in consonance with the MMT long range plan. HQ DARCOM Numerical Control (NC) Working Group developed the plan for orderly and judicious expansion of NC technology throughout DARCOM. A TRIDEA digitizing and drafting machine was obtained through a prior effort.

SUMMARY

The objective of the project was to improve manufacturing efficiency and obtain a quick response flexibility in the preparation of numerical control tapes (part programming). A "UNIAPT" mini-computer based part programming system with three dimensional contouring was obtained. The system consisted of a General Automation SPC 1660 computer, magnetic disk, a teletypewriter, a high speed tape reader, a high speed tape punch, a line printer-card reader, and all the necessary system software. Six post processors were also obtained for NC lathes and machining centers. The NC tape preparation was interfaced with the TRIDEA drafting and digitizing system for cutter location path display and verification. A Computer Numerical Control (CNC) Wadell lathe was linked with the computer system to allow direct transmission of machine instructions.

BENEFITS

A computer assisted NC tape preparation system is operational; personnel have been trained and have effectively operated this system. NC tapes were prepared for two NC lathes and four machining centers to machine components for fire control and ammunition items.

A savings in direct labor manhours was achieved in tape preparation time in the first year of operation. An increase in the workload handling capability of the NC machine tools was achieved.

IMPLEMENTATION

The system established by this project was operational in 1975 and was used to prepare NC tapes for fire control and ammunition components for production and R&D quantities. The system was augmented with graphics terminals, interactive computer aided design software, and a high speed plotter. The augmented system has been operational at US Army Armament Research and Development Command (ARRADCOM, Dover, NJ) since 1978 for use in support of R&D prototype development, production engineering studies, and related MMT efforts. A schematic of the system information flow is illustrated in Figure 1.

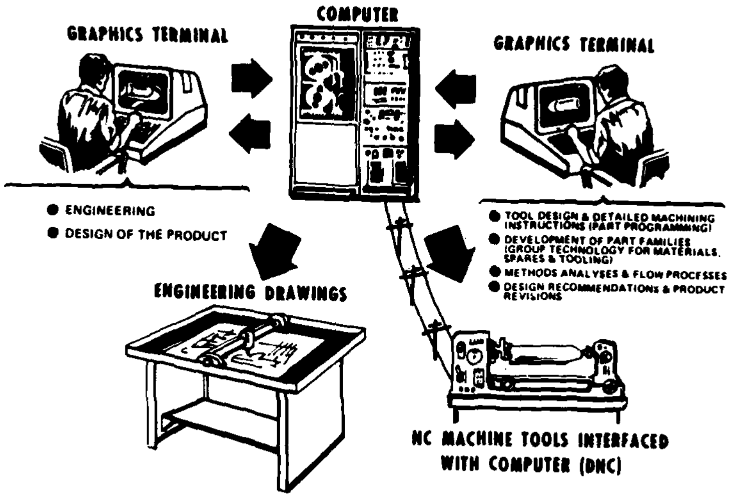


Figure 1 - Information Flow of Computer System

MORE INFORMATION

Additional information can be obtained from Mr. Stan Hart, ARRADCOM, ATTN: DRDAR-TSF, Dover, NJ 07801, AV 880-2706 or Commercial (201) 328-2706.

Summary Report was prepared by Stephen A. McGlone, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

ELECTRONICS

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects R75 3134 and R77 3134 titled, "Manufacturing Methods for Production of Field Effect Electron Emitters" were completed by the US Army Missile Command in June 1978 at a cost of $275,000.

BACKGROUND

Since the discovery of field emission (electron emission from a conductor into a vacuum caused by a high surface electrical field), attempts have been made to utilize the cold cathode for practical applications. However, widespread use of the cold cathode has not occurred because of electron current instability and limited lifetime. These technical difficulties were caused by requirements for extremely high electric fields (10^6 volt/cm), high voltages (10^3 volt) and ultra-high vacuum (10^{-9} torr). Theoretically, the only requirement is the high electrical field. Modern ultra-high vacuum techniques and pulsed voltages have improved stability and renewed interest in field emission application to electronic devices.

Multiple-pin thin film field emission cathodes have shown great promise as high current density electron sources. A device of this type, comprised of oxide-metal composites with free standing tungsten fibers has been successfully demonstrated in the laboratory. Manufacturing techniques were required to reduce the high fabrication costs of this technology.

SUMMARY

The objective of this effort was to establish production processes for fabricating melt-grown oxide-metal composites for field effect electron emitting cathode structures. The work was performed by Georgia Tech and was divided into two phases.

Phase I was an investigation into the growth of oxide-metal composites and the fabrication of cold field effect emitters. The composites contained 10^7 single crystal, 0.5 μm diameter, tungsten fibers per cm^2, aligned in parallel and uniformly spaced in a uranium oxide (UO_2) matrix. Urania tungsten powders from four vendors were evaluated and optimum growth procedures for the uranium oxide-tungsten (UO_2-W) composites were established.

Parameters considered included sample size, starting oxide metal compositions, solidification rate, oxygen to uranium ratio (O/U), influence of premelting ingot density, sintering properties, and control of the molten zone. These studies resulted in a procedure for the routine growth of UO_2-W composite ingots weighting up to 500 grams. Procedures for slicing the ingots into wafers, brazing the wafers onto high vacuum materials, machining the composite into selected emitter geometries and exposing, and shaping fibers by chemical etching and ion milling were developed.

Prototypes were tested and current densities of over 1 amp/cm^2 were obtained.

Phase II established manufacturing processes for UO_2-W composite <u>low voltage</u> field emitter (LVFE) using thin film technology. The structure of the LVFE is basically the same as that of the thin film field emission cathode: single crystal tungsten fibers each centered in individual conical holes in a thin film SiO_2 insulator layer and a thin film molybdenum metal extractor layer.

Sequential vacuum deposition of the SiO_2 insulator and the Mo metal by electron beam evaporation onto the oxide matrix produced cone shaped growths. The procedure electrically isolated the metal grid structure from the UO_2 substrate and W fiber cathodes.

After deposition, the cone deposits on the fiber tips were removed by ultrasonic vibration and chemical etching, see Figures 1 and 2. The technique provides for independent dimensional variation of each structural feature.

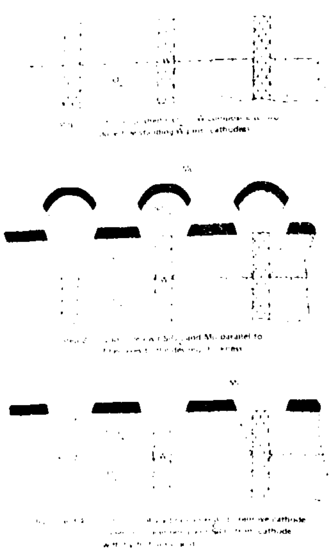


Figure 1 - Schematic of Low Voltage Field Emitter Processing

The shape of the fiber tip may be varied from a right circular cylinder to a pointed tip by Argon milling. Sufficient electric fields were produced to emit electrons from the W fiber tips with the grid biased at 100-200 volts by placing the fiber tips at the level of the metal extractor grid.

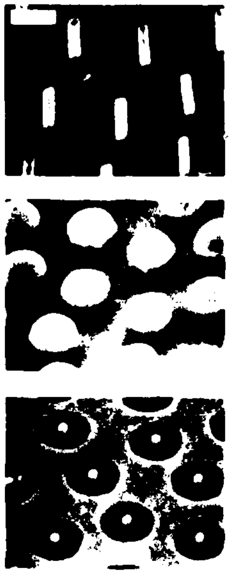


Figure 2 - Scanning Electron Micrographs of the Low Voltage Field Emitter After the Processing Steps shown in Figure 1.

Electrical properties of the SiO_2 thin film insulator were investigated and a mathematical model was developed to predict emission current values for the LVFE geometry. The prototype cathodes were emission tested in a pulsed mode and current densities in excess of 15 amps/cm^2 were achieved.

BENEFITS

This effort developed manufacturing procedures that significantly reduced the fabrication costs of oxide-metal composite material matrices. New methods for emitter fabrication used commercially available equipment to cut costs appreciably.

Areas of application include electronic devices that now use thermionic emitters, gas laser devices, infrared devices, and electron beam welders. Another area of application includes devices for increased fuel economy that employ charge injection into liquids.

IMPLEMENTATION

The effort's results have been documented and furnished to all the Military Services and to private Industry. This has resulted in the participation of all Services and several contractors in testing the material for specific device applications in a number of missions and requirements.

MORE INFORMATION

Additional information may be obtained from Mr. Joe Shelton, MICOM, AV 746-4652 or Commercial (205) 876-4652. The contract is DAAK40-77-C-0096.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 272 9365 titled, "Packages for Microstrip Integrated Circuits" was completed by the US Army Electronics Command in December 1974 at a cost of $174,000.

BACKGROUND

Microstrip Integrated Circuits (MIC) are unique and complex microcircuits. Many different MIC's are built to perform various functions and are housed in packages of various sizes and shapes. Industry made no attempt to develop standardized housings or fabrication techniques to reduce unit cost of MIC's because the devices are primarily used in military applications and demand is limited.

The AN/PPS-15 Very Short Range Radar was scheduled for the first production buy in FY74. This unit uses numerous MIC's making it an excellent candidate for standardization of the MIC packages.

SUMMARY

Microwave Associates, Burlington, MA, contracted to develop a family of packages for MIC's operable over a frequency range of 1.0 to 18.0 Gigahertz with a production capability of 100 per month. The latest techniques for fabricating integrated microstrip were utilized to establish a manufacturing facility for the microstrip integrated circuits. The units consisted of four basic packages to accommodate substrates in the following sizes: 1 x 1, 1 x 2, 2 x 2, and 2 x 4 inches, see Figure 1.

The fundamental tasks were concerned with packaging, welding, hermetic sealing, and repairability of the MIC's. Production tolerances of the pa ages and electrical performance of connectors were evaluated and proper signs chosen.

The basic production processes used demonstrated that high quality MIC packages can be designed and fabricated at low cost on a production basis. Some of the manufacturing processes used were impact extrusion of housing, drawing and coining of covers, soldering without flux in a hydrogen atmosphere furnace, numerically controlled machining of the housing, and Tungsten Inert Gas (TIG) welding of aluminum components.

Figure 1 - Modular Packages for Microwave Integrated Circuits

The overall production yield using the materials and techniques developed including TIG welding was better than 97%. The failures were primarily contaminated non-repairable welds. Units were readily opened for repair and resealed by the same TIG welding process. Hermetic integrity of the welds showed that leak rates of less than 1×10^{-8} ATM cc/sec were achieved in the majority of the units.

BENEFITS

This project demonstrated that high quality hermetically sealed Microstrip Integrated Circuit packages can be designed and fabricated in high production quantities at low cost. The packages can be opened for repairs and resealed at least once while retaining hermeticity. The package design avoids organics internally so that uncased semiconductor devices can be used without contamination.

IMPLEMENTATION

The housings developed during this project are not used by Microwave Associates mainly because there is no standard microwave integrated circuit.

The package has to be adapted to the size of the circuit it houses. However, there have been two by-products of this project. Prior to this contract, RF connectors available to industry gave very unsatisfactory performance. Microwave Associates exercised more stringent control of the manufacturing process resulting in an improved hermetically sealed RF connector. The connector is now commercially supplied by Omni Spectra Incorporated. The second benefit was the refinement of Tungsten Inert Gas welding to make it usable in production. Microwave Associates is currently using this technique for building the SPARROW Missile target detection device for the Navy.

MORE INFORMATION

Additional details may be obtained from Mr. James Kelly at ERADCOM, AV 995-4803 or Commercial (201) 545-4803.

Summary Report was prepared by Edward F. Zajakala, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 273 9402 titled, "Epitaxial Growth of Bubble Film Memories for Computers" was completed by the US Army Electronics Command in March 1977 at a cost of $235,000.

BACKGROUND

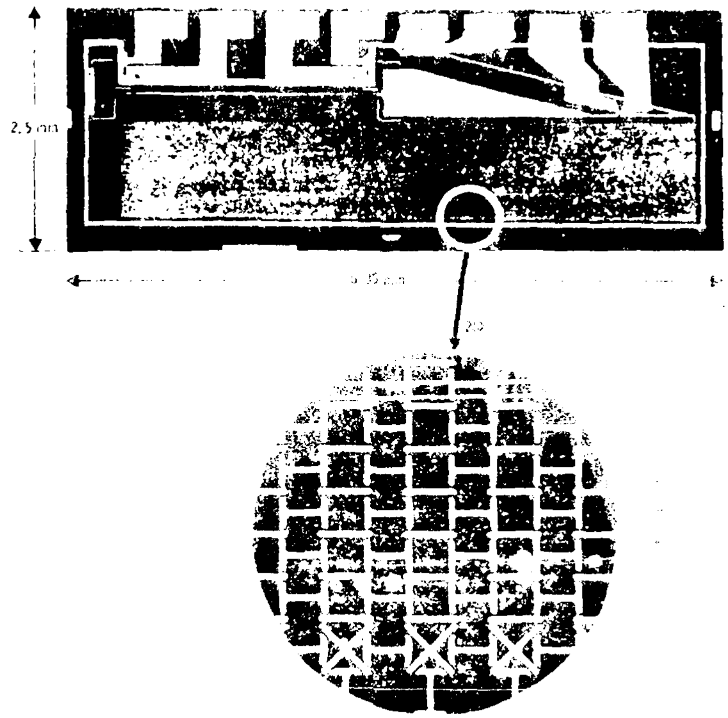
At the time of contract award, March 1973, magnetic bubble memory devices were a relatively new, promising technology. Magnetic bubble domain memory elements possess significant advantages as a replacement technology for disc, drum and tape memories, especially in military and space environments. Some of the advantages are: non-destructive read-out, very high reliability, high bit density, high chip capacity, and low power dissipation. These attractive bubble device technical features, combined with a low cost/bit production for mass memory applications, provided the impetus for establishing this project.

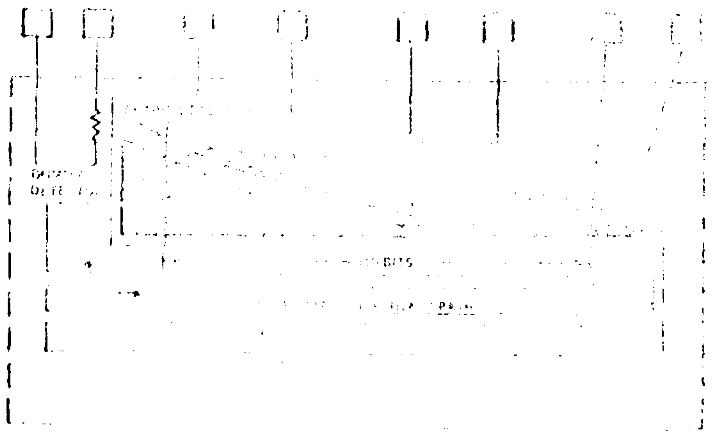
SUMMARY

The objective of this project was to advance state-of-the-art production techniques for magnetic bubble domain memory devices. The development of new device designs or functions was not included in this effort. Rockwell International Corp. demonstrated the required bubble memory specifications by fabricating a four-register/die pattern, 1024 bit total capacity, 24 µm period device. This element utilizes off-chip data multiplexing, operating at 125 KHz, to produce an effective 500 KHz data rate.

Five engineering samples and ten first article units were produced. The project was modified prior to completion to accommodate significant advances in bubble technology. The pilot run was made on a 20,480 bit serial loop, µm period shift register capable of higher intrinsic data rate operation ..r a wider temperature range, see Figures 1 and 2. The pilot line achieved a production rate of 500 devices per week.

Thin film silicon dioxide (SiO_2) dielectric and an aluminum copper (Al-Cu) alloy conductor metallization were epitaxially deposited onto a high quality commercially available single crystal garnet ($Gd_3Ga_5O_{12}$) substrate. The films were electron beam evaporated sequentially in a single vacuum cycle. The following significant manufacturing techniques and material improvements were made: Aluminum copper alloy was substituted for gold as the conductor material, Single mask level permalloy detector replaced the thin permalloy layer, two mask level detector design which was standard at the start of the contract, Ion beam milling, with Argon as the milling ion, was used to achieve ultra-high fidelity pattern definition [illegible] chemical etching as state-of-the-art production, [illegible] (10.6 [illegible] wavelength) achieved an accurate [illegible] technique for the [illegible], which was previously diced [illegible] thermal compression bonding was utilized [illegible] the bubble chip wire interconnections.





BENEFITS

Improvements introduced by this project enhanced device reliability and reduced power dissipation. Simpler fabrication methods resulted in fewer process steps and higher yields. Bit density and chip capacity were increased and cost per bit was reduced by a factor of ten.

IMPLEMENTATION

Project results were documented in the final report distributed to industry. This documentation can be utilized for expanding the resultant pilot rate of 500 per week to meet military needs.

MORE INFORMATION

Additional information may be obtained from Mr. Thomas Collins, CORADCOM, Ft. Monmouth, NJ, AV 995-2006 or Commercial (201) 544-2006. The contract was DAAB05-73-C-2057. NASA and the Air Force have applied this technology.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 274 9426 titled, "Manufacturing Methods for the Fabrication of Large Area Silicon Avalanche Infrared Detectors" was completed by the US Army Electronics Command in January 1977 at a cost of $247,000.

BACKGROUND

The Silicon Avalanche Infrared detector is a solid state photodiode designed to collect and amplify radiation at the 1.06 micron wavelength. Existing mechanical fabrication methods were costly, involved hand labor, and resulted in irregularities in the silicon chip surface contour. New techniques were required to produce large quantity, low-cost devices.

SUMMARY

The project's objective was to establish production processes for improving quality and increasing the yield of large area silicon avalanche detectors. RCA Limited at Quebec, Canada demonstrated the technology by fabricating a pilot run of 100 units. The photodiode chip has a modified p-π-n structure in which a narrow portion of the substrate material beyond the metallurgical junction is artificially doped to provide a higher concentration of acceptor states. The resultant p-π-p-n structure is depicted in Figure 1.

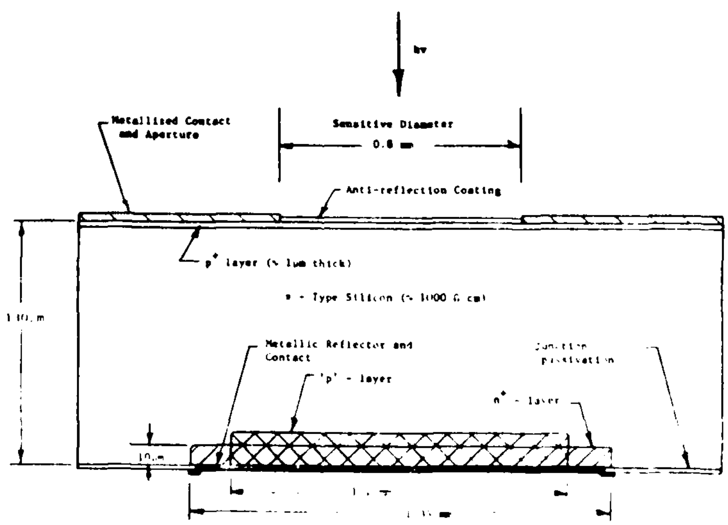


Figure 1 - The Avalanche Reach-Through Structure

Features of practical importance are the ohmic contact layer at the window surface of the chip, the passivation of the jun^tion surface, and the existence of a channel stopper diffusion surrounding the junction.

Work performed included photoresist masking, etching, boron ion implantation, boron and phosphorous diffusion, passivation, lapping, boron nitride gettering, and Al-Cr-Au surface metallization. Reproducible diffusion profiles were ensured by controlling the total dose of the dopant atoms entering the wafer, diffusion conditions, and growth of the passivation layer.

Improvements in boron dose uniformity were achieved by the ion implantation beam Scan method for writing on the wafer. This technique served to narrow the wafer breakdown voltage distribution. After ion implantation, the boron was driven into the silicon by high temperature diffusion in an oxygen ambient. This method simultaneously grew the masking oxide for the phosphorous junction doping step. Passivation consisted of a thermally grown oxide layer overlaid with a secondary passivation of silicon nitride and a final capping of deposited silicon dioxide.

After Al-Cr-Au metallization, the wafer was scribed into chips and assembled into a TO-5 package. Figure 2 shows a completed SCS 467 unit. The silicon chip was mounted on the junction side and isolated from the case by a gold metallized ceramic pedestal. The purpose of rear-entry operation of the photodiode was to preserve adequate spectral response at the short wavelength end of the spectrum. The package had an antireflective coating and was hermetically sealed behind a flat glass window.

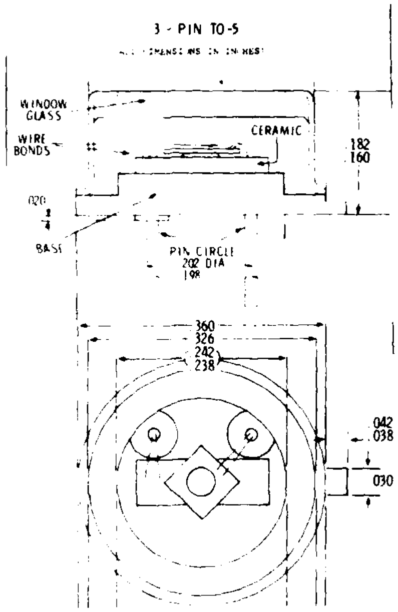


Figure 2 - Assembly of SCS 467

BENEFITS

As a result of the improved manufacturing processes established by this project, the photodetector price has decreased from $335 each to $175 each when produced in large quantities.

IMPLEMENTATION

The large area photodetector is now available as a production item. The photodetector fabricated with the technology developed by this project is currently used in the AN/GVS-5 Laser Rangefinder Module.

MORE INFORMATION

Additional information may be obtained from Mr. Joseph Sanders, ERADCOM, AV 995-4824 or Commercial (201) 544-4824.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 273 9614 titled, "Measure for High Current, Fast Switching Transistor" was completed by the US Army Electronics Research and Development Command in April 1976 at a cost of $102,610.

BACKGROUND

When this project was initiated in 1972, power transistors for fast switching applications were breaking down due to high voltage spikes and had slow turn-off times. Power transistor producers knew how to overcome these problems but had not done the production engineering to get the cost down. The Army Mobility Command needed the transistors for use in battery chargers, static isolators, and communications systems.

SUMMARY

The Army Electronics Command contracted the work to Silicon Transistor Corporation (STC), Chelmsford, MA. STC used a double epitaxial process to obtain the high voltage structure wherein the potential is supported across the high resistivity portion of the collector region as well as the base region. Both the collector and the base are epitaxially grown on the silicon substrate. This structure permits routine production of transistors with breakdown voltage between the collector and emitter exceeding 300 volts where a single-diffused process provides only 200 volts.

High current transistors are characterized by large area and by emitter structures with long peripheries. Length is obtained by serpentine layout of the emitter pattern, see Figure 1. Use of silicon having low dislocation density is important because the transistor covers such a large area - in this case 550 mils (1/2 inch) square. Fast switching times are obtained with very shallow base diffusion.

Established heat transfer methods were used to bond the silicon chip to the molybdenum mounting pad. The chip was metallized on the back with aluminum and then titanium-silver-gold, and a gold-tin preform was used to solder the chip to the gold plated moly pad. Aluminum wire leads were ultrasonically bonded between base and emitter contact areas and lead-in posts.

Figure 1 - Encapsulated .550" Chip, TO-115 Package

BENEFITS

The contract resulted in the establishment of processes for making 90 amp, 200 volt fast-switching transistors on a production basis. Two hundred sample devices were delivered for test. Units are now available commercially from several semiconductor houses and are able to switch on and off rapidly for commutation applications.

IMPLEMENTATION

Processes developed here were used by STC to produce transistors for the PP-4126 battery charger and power converters for the PP-6183 Isolator used in amphibious craft.

MORE INFORMATION

Additional data may be obtained from the contractor's final report "Production Engineering Measure for High Current, Fast-Switching Transistors," contract DAAB05-73-C-2032, 19 July 1975, or from Mr. John Plaisted, STC, Commercial (617) 256-3321, ext. 54.

Summary Report was prepared by C.E. McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 274 9639 titled, "Automation of Production Methods for Multi-Alkali Photocathode Processing" was completed by the US Army Electronics Research and Development Command in June 1976 at a cost of $713,500.

BACKGROUND

Widespread acceptance of night vision equipment has increased the demand for such units. However, industry was not tooled for high rate production and its older manual methods were not suited for scale-up. Newer, more productive methods of making the elements used in night vision devices were sought and several MMT projects were initiated by the Night Vision Labs with ERADCOM support. These projects dealt with the major elements in night viewing equipment including phosphor screens, photocathodes, inverters, and peripheral components such as power supplies, voltage multiplier circuitry, and housings. This project dealt with photocathodes.

Work was contracted to ITT Electro Optics Products Division, Roanoke, VA, and to NI-TEC, Skokie, IL. ITT agreed to further develop the external process for applying multi-alkali coatings to photocathodes, and NI-TEC agreed to improve the internal application method. External and internal refer to where the processing is done; in the former, the photocathode is processed outside the tube and then transferred in a vacuum system to the tube, see Figure 1.

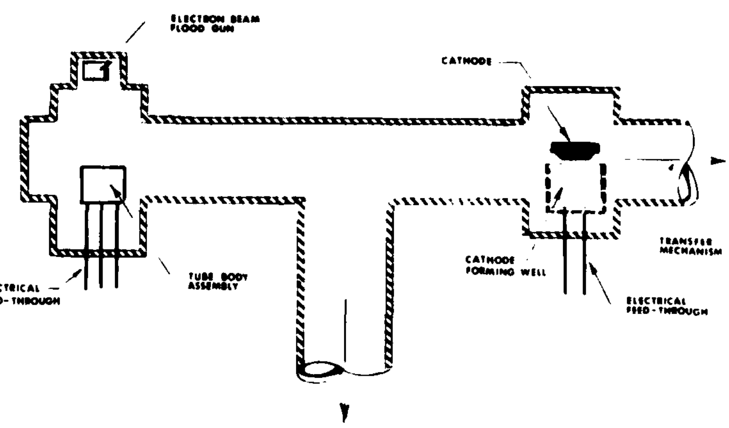


Figure 1 - External Processing

In the latter, the photocathode is processed in position in the tube as shown in Figure 2.

Figure 2 - Internal Processing

SUMMARY

ITT developed the technology and capability for computer controlled automatic deposition of multi-alkali photocathodes external to the image intensifier. The firm's work was divided into two parts. In Phase I automated processing equipment was designed and built and a computer program for fully automatic photocathode deposition control was developed in Phase II. The first run of photocathodes had a sensitivity of 347 microamps per lumen output. During the proof run, sensitivity was improved to 391 microamps per lumen; 275 microamps per lumen is satisfactory and thus an output 40% over specification was attained. Uniformity of output over the cathode surface was also improved.

NI-TEC likewise had a two-phase contract to automate photocathode processing but by the internal method. In Phase I instrumentation, controls, and a computer program that duplicated manual methods were designed. In Phase II attempts were made to isolate the controllable factors and then optimize the program thru iteration. Following this, 200 samples were processed for evaluation. The objectives of increased and more uniform sensitivity were attained in that sensitivity averaged 260 microamps per lumen with a standard deviation of 31.

Equipment employed at NI-TEC includes an EPI-118 mini-computer with 16K words of core memory, a Barber Coleman oven control, a microammeter and other sensors and controls. The major input to the computer is the current from the photocathode being processed; the major outputs are the currents to the controls of the four alkali gas generators.

BENEFITS

As a result of this investment, both contractors developed technology and capability for computer controlled deposition of multi-alkali photocathodes in image intensifiers. ITT advanced its external method by processing the cathode in a forming well, and while still in the vacuum chamber, transferring it to the tube body for assembly. NI-TEC optimized its internal methods by applying computer control to vary chemical processing rates, temperatures, and cooling rates. Both firms improved product uniformity and sensitivity thru several iterations and refinements of the software. ITT increased photocathode sensitivity from 347 to 391 microamps per lumen and reduced the standard deviation to half that permitted. NI-TEC felt that the program could generate cathodes of 375 microamps per lumen for a 40% improvement over initial runs.

IMPLEMENTATION

ITT is using the automated photocathode processing equipment at its Electro Optics Products Division at Roanake, VA. Also, the ITT design has been introduced at Litton Electron Tube Division and is in use there. Litton's multi-port batch processing equipment developed on project 274 9750 is readily adapted to automatic processing.

NI-TEC used company funds to incorporate the results of this contract into their production build-up program. They realized a savings of 1.2 hours or approximately $50 per tube. Approximately 25,000 tubes have been purchased by the Army since this process was developed and cost savings of approximately $1,250,000 have been realized.

MORE INFORMATION

Additional data may be obtained from the final contractor reports on these two contracts. ITT's document is titled, "P.E.M. for Automatic Production for Multi-alkali Photocathode Processing," Contract No. DAAB05-74-C-2521. NI-TEC's document is titled, "Production Engineering Measure for Automation of Multi-alkai Photocathode Processing," Contact No. DAAB05-74-C-2520. Another source of information is Mr. Sheldon Kramer, optics engineer, Night Vision and Electro Optics Labs, Ft. Belvoir, VA, AV 354-6265 or Commercial (703) 664-6265.

Summary Report was prepared by C.E. McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 274 9750 titled, "Fabrication of 18mm Wafer Image Intensifier Tubes by Batch Processing Methods" was completed by the US Army Electronics R&D Command Night Vision and Electro-optics Laboratory in December 1979 at a cost of $678,515.

BACKGROUND

Expanded requirements for image intensifier tubes for use in night vision goggles indicated that a shortage of processing capacity would result unless a program to scale up existing processing equipment was undertaken. Image intensifier tubes were processed on single-port equipment and capacity could be increased by adapting a five-port system developed by Litton Electron Tube Division, San Carlos, CA and increased further by designing a ten-port system. Functions accomplished in the processor consist of tube evacuation, photocathode formation, microchannel plate outgassing, phosphor screen outgassing, and sealing of the tube. A gun for electron beam scrubbing was to be included in the system.

SUMMARY

Litton Electron Tube Division contracted a two-phase effort. Phase I was to modify its new five-port design to include state-of-the-art techniques for electron beam scrubbing, tube evacuation, photocathode formation, MCP and phosphor screen outgassing, and sealing by soldering a double indium seal. Phase II was to try to expand the technology to a ten-port system. Phase II was unsuccessful but Phase I was successful. The resulting computer controlled wafer image tube processor is shown in Figure 1.

Phase I proved the feasibility of batch processing. The firm's five-port design was modified to include electron beam scrubbing and indium seal soldering. Photocathodes were formed by introducing successive atmospheres of antimony, potassium, sodium, and cesium; photocathodes made in this equipment met the specifications. After the five-port equipment was proven, Litton submitted plans for a processor containing ten ports.

Phase II covered the design, fabrication, and evaluation of a ten-port station based on the five-port design. Problems with vacuum draft were solved with baffles and plates, but, the station was uneconomical to operate because increased mass and volume lengthened processing and bakeout times to more than double that expected. Work on the ten-port system was abandoned and the contract terminated.

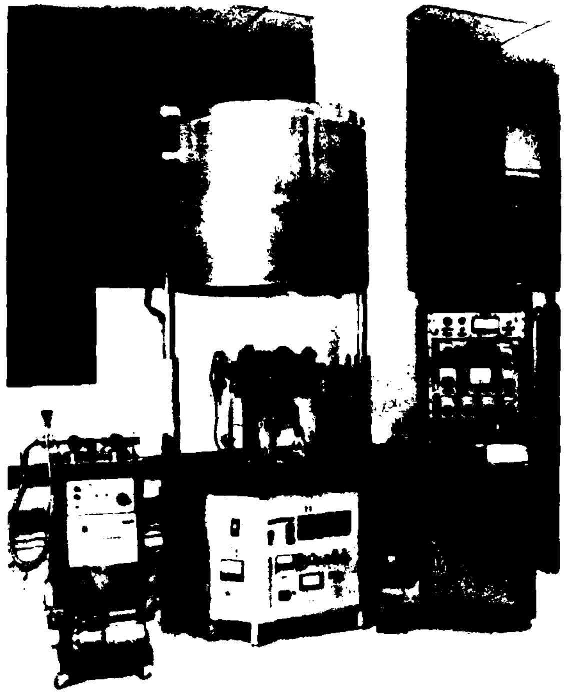


Figure 1 - 5-Port Computer-Controlled Wafer Image Tube Processor

BENEFITS

Phase I of the contract proved the feasibility of batch processing wafer image intensifier tubes. The five-port station reduced capital equipment cost 50% when compared to five existing single port stations and cut labor hours 67% or $75 per tube. Litton is using five-port stations exclusively and has thereby avoided the expenditure of $600K for single-port systems

The improved efficiency of the new manufacturing equipment resulted in reduced cost of night-vision goggles. Approximately $1.5 million was saved on production contracts for AN/PVS-5 night vision goggles and an additional $1.5 million savings is expected on future procurements.

IMPLEMENTATION

Litton is using five port stations exclusively in production of second generation image intensifier tubes for AN/PVS-5 Night Vision Goggles.

Final engineering reports were distributed to twenty Government offices, five image tube builders, and ten other interested firms.

MORE INFORMATION

Additional information is available in the Quarterly and Final Engineering Reports prepared on contract DAAB07-74-C-0370. Copies may be obtained from the Defense Technical Information Center using AD #BO 25838 for the Final Report. Other assistance may be obtained from the project engineer, Mr. Donald Jenkins, US Army R&D Command Night Vision and Electro-Optics Lab., Ft. Belvoir, VA 22060, AV 354-1424 or Commercial (703) 664-1424.

Summary Report was prepared by C.E. McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 276 9783 titled, "Production of High Resistivity Silicon Material" was completed by the Electronics Research and Development Command in June 1980 at a cost of $501,000.

BACKGROUND

Increased demand for high purity silicon wafers for fabrication into photodetectors for use in laser seeker ammunition far outstripped domestic capacity for its manufacture. Wafers were obtainable from Wacker Chemical Corp in West Germany on a commercial basis but the facility was vulnerable to foreign military takeover. Prudence dictated that a domestic source be established and maintained.

Two major processes are required for the manufacture of high purity silicon; the first is purification of silane from a special sand and formation into rods of polycrystalline silicon. The second is vacuum zone refining of the polycrystalline rod into single crystal rod. A minor finishing process consists of cutting the rods into wafers and polishing both sides.

SUMMARY

The Industrial Products Division of Hughes Aircraft Co., Carlsbad, CA established methods for producing detector grade silicon having resistivities of 15,000 to 30,000 ohm-cm with dislocation densities under 1,000 per sq. cm. High purity silicon was processed from high purity polysilicon rods using multiple-pass vacuum float zoning equipment. The latter equipment is unique in that it uses no cruicible to hold the material. The facility established at Hughes is now a domestic source of high quality silicon and can supply specified material to detector manufacturers.

Procedures were also established for fabricating wafers by diamond gang-sawing from the 12" long rods and lapping and polishing both sides to precise dimensions and surface finish. Double sided free polishing of the wafers was employed after being developed on this project. Using special pads and compounds, it chemically-mechanically polishes both sides of the wafer simultaneously. A zirconium-silicate slurry is used in the first rougher cut and silicon gel in the final polish with different pads used in both steps.

High resistivity wafers were provided to RCA Quebec for processing into quadrant detectors; results confirmed the suitability and high quality of the slices. Detectors had lower dark currents than those made from other material and were excellent detectors of 1.06 micron laser radiation. High resistivity resulted from low boron concentration and uniform resistivity gradient across the slice.

BENEFITS

Work at Hughes resulted in the establishment of procedures and equipment for vacuum zone refining of polycrystaline rods into high purity single crystal rods that were later cut and polished into wafers that were processed into quadrant detectors.

Also, new double sided polishing procedures described above were developed to eliminate wafer taper, surface damage and edge chipping, and to provide two highly polished surfaces.

Data from these pilot operations were analyzed with respect to yield and cost; it became apparent that cost could be reduced by automating the zoning process; follow-on project 279 9783 addresses this improvement.

IMPLEMENTATION

The manually controlled facility established at Hughes constitutes a domestic source of very high quality silicon and is capable of producing material to the specifications of detector manufacturers. Two zoners provide 3.5 kilograms per month; to produce 15 kilograms per month would require nine manually operated zoners or four automated machines. A new project was initiated to develop automated vacuum zone refining equipment and procedures. It should reduce the cost of wafers by a factor of 2.8 or 3.

The double sided polishing procedure and equipment was also implemented into production as a result of this project. Resultant high resistivity silicon is used in quadrant detectors for Copperhead, Hellfire, Maverick, and Paveway missiles.

MORE INFORMATION

Additional information may be obtained from the final Technical Report AFML-TR-78-171 titled, "Manufacturing Processes for Detector Grade Intrinsic Silicon," or by contacting Mrs. Clair Loscoe, CORADCOM, AV 995-4809 or Commercial (201) 545-4809.

Summary Report was prepared by C.E. McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 375 3119 titled, "Production Methods for Laser Guidance Designators" was completed by the US Army Missile Command in July 1976 at a cost of $350,000.

BACKGROUND

Laser Guidance Designators are essential to all laser terminal homing systems. Performance of the designators is high but over-specification of their electro-optical (EO) components such as laser rods, Pockels cells, polarizers, precision prisms, and lenses results in excessive unit cost. High volume, multi-element fabrication techniques, dynamic testing methods for active elements, and procedures that are usable by low skilled operators were needed for large quantity manufacture of laser designators.

SUMMARY

The objective of this project was to establish cost effective production and testing methods for electro-optical components used in Laser Guidance Designators. Martin Marietta Corp performed the work. The flow diagram in Figure 1 identifies the steps and main thrust of the effort.

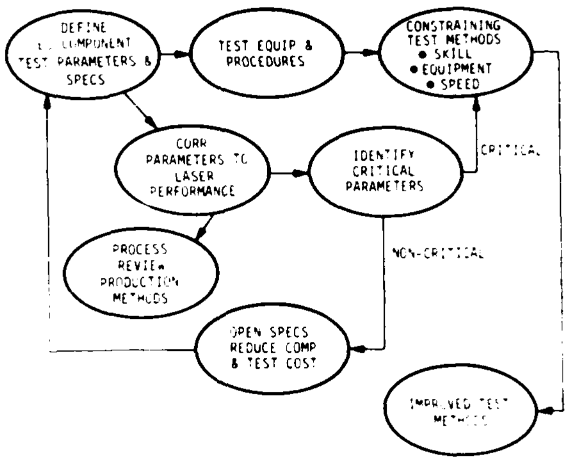


Figure 1 - Flow Diagram for Process Review of Production Test Methods

Twenty-two EO components were identified and categorized as to individual test parameters, specifications, and tolerances. The components include YAG laser rods, Pockels cells, polarizers, filters, mirrors and precision prisms, and lenses. Tolerance performance tradeoff studies made on high cost items revealed excessive tolerances which could be relaxed without affecting system performance. Based on this information, test equipment and test procedures were developed.

Six improved test methods which substituted dynamic tests for static tests were introduced for critical EO components. This reduced testing time by approximately 50 percent. Dynamic tests generated and performed on laser rods include: (1) beam divergence, output energy efficiency, and far field beam profile; (2) transmission reflectivity of anti-reflectant coatings and single pass gain; and (3) rod flatness, parallelism, and extinction pattern under crossed polarizers (isogyre pattern) all with and without optical pumping. Figure 2 shows the complete equipment set up for one of the specialized test stations designed to test specific dynamic performance characteristics of pulsed laser rods.

Figure 2 - Specialized Dynamic Test Station for Laser Rods

At this station, beam divergence, output energy efficiency, and far field beam profile are simultaneously recorded. A dynamic test apparatus was also built and used to test Pockels cell/polarizer assemblies. This equipment provided measurements of transmission, bias voltage, quarter wave holdoff voltage, switching time, and polarizer alignment.

Cost effective manufacturing processes that replace lab methods were introduced for prisms and lenses. These operations include multiple element spot blocking, multiple on-block generating, glass pressing, pellet grinding, high speed polyurethane lap polishing, large capacity lapmaster polishing and grinding, and automatic centering.

BENEFITS

Overall benefits and cost savings resulting from this study were estimated by using three production case studies of 500 systems, 1000 systems, and 2500 systems, each spread over a five year production span. Cost savings resulting from tolerance relaxations on special elements, improved test methods, and production fabrication methods range from $262,000 on 500 systems to $1.72 million on 2500 systems.

Project achievements should result in real and substantial cost reductions in manufacturing laser guidance designators.

IMPLEMENTATION

Design tradeoffs with respect to component tolerance and system performance are now providing the basis for designing lasers to predetermined system requirements. Copies of a final report have been distributed to private industry and all military services. The results of this project have been documented and are available for additional implementation.

MORE INFORMATION

Additional information may be obtained from Dr. George Emmons, MICOM, AV 746-1475 or Commercial (205) 876-1475. The contract was DAAH01-75-C-0186.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 376 3224 titled, "Screening of Electronic Components" was completed in August 1978 by the US Army Missile Command at a cost of $299,234.

BACKGROUND

Electronic component failures are a major contributor to missile assembly test rejections in high level systems. An alternative is to use more reliable components; however, they cost more (an order of magnitude). Another alternative is to use low cost components insuring reliability through screening (inspecting). Various methods have been employed to screen low cost components but many are costly and ineffective in detecting marginal conditions or are so severe that uncertainty exists about the deleterious effects of the test on the long-term reliability or life expectancy of the circuit. In some cases, screening techniques are also needed for high reliable components where 100% inspection is required.

SUMMARY

The object of this project was to reduce the cost and increase the reliability of electronic components by evaluating and developing low cost military screen tests for components and hybrid microcircuits. Because of the number of screen tests available and the large number of permutations in sequencing, test efforts were directed toward three areas considered critical to MICOM: 1) temperature cycling and stabilization bake test for both MOS/LSI and hybrid circuits, 2) moisture analysis, and 3) in-process control tests for custom designed MOS/SLI.

TASK I: The Effectiveness of Temperature Cycling and Stabilization Bake as Screen Test for Marginal Wire Bonds.

Wire bond failures are considered to be a major cause of microcircuit failures; it is estimated that 23-32% of all failures are attributed to wire bond anomalies, see Figure 1. Failures result from suboptimum machine bonding parameters, contaminants, and physical anomalies. It is highly desirable to develop a screen test that will "single out" the marginal bonds, yet be nondestructive to the others. This task evaluated the effectiveness of temperature cycling and stabilization bake tests (identified in MIL-STD-883) in weeding out marginal bonds.

Figure 1 - Gold Wire Bond to Thin Film Aluminum-
Overbond Condition (magnification 530x)

Marginal wire bonds were intentionally fabricated and subjected in controlled experiments to various temperature cycles and stabilization bake conditions, both independently and dependently.

TASK II: Evaluation of Moisture Analysis Methods and Investigation of Moisture Effects on Microelectronic Devices.

Excessive moisture, several thousand parts per million by volume (PPMv), in microcircuit packages is undesirable. The exact amount has not been determined but moisture has been identified as an essential component for several failure mechanisms. This observation led to two important questions: 1) what concentration of moisture can be tolerated?, and 2) what methods are suitable for accurately measuring moisture concentrations?

This task was directed toward evaluating the various methods presently used for analyzing moisture concentration and investigating the effects of measured moisture concentrations on selected microelectronic devices. Samples were prepared and tests were conducted to investigate the effects of different moisture concentrations on a few selected microelectronic devices.

TASK III: In-Process Controls for Custom MOS/LSI Fabrication.

MOS/LSI producers have their own process controls and screen tests but there is little information on the correlation of these controls/tests with long-term performance. The objective of this task was to investigate in-process controls and select those which would most effectively produce long-term storage and operating life requirements. Also, the effectiveness of temperature cycling and stabilization bake as screen test was evaluated.

Investigations of in-process control tests to determine the integrity of the gate dielectric, to detect the presence of mobile ion contamination, and to determine the stability of the composite silicon dioxide/silicon nitrate dielectric were made. Tests included were: dielectric integrity or pinhole detection tests, mobile ion contamination test, and a nitride stability test.

BENEFITS

<u>TASK I</u>: The work performed indicated that the MIL-STD-883 screen tests, performed as individual tests, required extended times or a large number of cycles before failures occur. The length of these tests makes them impractical for 100% screen testing. Three new tests were identified and recommended.

<u>TASK II</u>: Results indicated there was no correlation between device failures and moisture content. This was unexpected but might be explained by a lack of contaminants in combinations with moisture or maybe the testing environments were not severe enough.

<u>TASK III</u>: Results are provided in the technical report for all the tests conducted.

IMPLEMENTATION

Test procedures, data, and results were published in a Technical Report MIRADCOM Report No. 76-3224, "Manufacturing Methods and Technology Program for Screening of Electronic Components" dated May 1978.

Three papers were presented at the 1978 International Society for Hybrid Microelectronics Symposium and the Government Microcircuit Application Conference. Results were also presented to the UC-13-3 Task IV Committee on Moisture Analysis Test. This test has been implemented in MIL-STD-883-Method 1008. In addition, the mobile ion detection test and nitride stability tests are being incorporated in design contract requirements for custom designed LSI chips.

The work performed under this MMT has identified additional areas where more work is required and appropriate efforts are underway.

MORE INFORMATION

For additional information and a copy of the final technical report, contact Mr. Austin, US Army Missile Command, AV 746-8437 or Commercial (205) 876-8437.

Summary Report was prepared by J.H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

INSPECTION AND TEST

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 076 5071 and 07T 5071 titled, "Improvement of TECOM Production Test Methodology Engineering Measures" was completed by the US Army Test and Evaluation Command in February 1979 at a total cost of $1,015,000.

BACKGROUND

These projects are a continuing effort to update and develop new production testing technology consistent with advances in the manufacture of Army equipment. The problem is that the equipment testing facilities and capabilities must be continually advanced in relevant technology areas to keep pace with the Army equipment production testing requirement. Advancement must be made both by increasing capabilities of existing facilities and by developing new methodologies, techniques, and facilities.

SUMMARY

These projects consisted of the following tasks: Automatic Data Collection Systems for Air Conditioners, Improved Container Test Capability, Application of Data Base Technology to Workload Scheduling, Acceptance Test Procedures, Refinement of Titanium Armor Specifications, Evaluation of Improved Borescope Techniques, Improved Fuel Handling Test Capability, Improved Methods for Safety Evaluation for General Equipment, Evaluation of Carbon Monoxide Contamination from Tank-Machine Guns, Validation of Acceptance Test Procedures, Test Operations Procedures, Joint Ballistic Test Conference Support, Artillery Projectile Spoiler Plate Design and Performance, Ammunition Drop Test Procedure, Maintaining Temperature During Test of Ammunition, Ricocket Fundamentals, and Small Arms Helmet Penetration.

Of these tasks, all have been completed with the exception of Test Operation Procedures, Acceptance Test Procedures and Validations, which are continuous efforts. The following tasks are representative of the objectives and results of the work accomplished by this project.

Improved Container Test Capability. The objectives of this task was to identify Container Test Facilities requirements. This included detailed facilities planning and design and equipment identification for testing oversized cargo containers and container related accessories and handling equipment. The specific facilities that were identified are: container handling, test rack, shock testing, and transporter equipment. The results of this effort are documented by specifications, drawing and make and model equipment requirements.

Application of Data-Base Technology to Workload Scheduling. The objective of this task was to develop a workload data base capability to assist in the management of the Aberdeen Proving Group testing program. This computerized testing information system would aid in scheduling projects, resources, establishing testing priorities and facilities utilization. The results of this task produced a computer program that analyzes the testing workload by cost center in terms of staffing and overtime requirements. It also has the capability to analyze the workload impact when the testing priorities are changed.

BENEFITS

In general, the benefits realized by the Army from these projects included improved production testing facilities, methodologies, techniques and data collection systems. Specifically, the benefits derived from the tasks cited herein are as follows:

Improved Container Test Capability. A facilities plan including specifications, drawing and equipment identification by make and model was completed and documented. This documentation is adequate to permit facilities construction and equipment procurements.

Application of Data-Base Technology to Workload Scheduling. A computer program was developed to aid in the management of the APG testing program.

IMPLEMENTATION

The results of these tasks have been implemented as follows:

Improved Container Test Capability. Task results have been used to formulate future construction plans.

Application of Data-Base Technology to Workload Scheduling. Results have been implemented at APG. The results have also been distributed to other similar activities.

MORE INFORMATION

Additional information may be obtained by contacting the project officer, Mr. G.H. Shelton, AV 283-3677 or Commercial (301) 278-3677.

Summary Report was prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 673 7063 titled, "Shock and Vibration Parameters for Use in Manufacture of Fire Control Systems" was completed by the US Army Armament Command in June 1974 at a cost of $134,000.

BACKGROUND

The nature of Ordnance equipment is such that it will be subjected to severe shock induced forces. Because of obsolete test specifications, a large portion of manufactured fire control instrumentation is being severely undertested or not tested at all. Since fire control systems serve the initial function of aiming the weapon and must be attached rigidly to the weapon in order to provide an exact alignment relationship with the gun bore, they are subjected to the weapon's dynamic environment. It thus became necessary to obtain field data on fire control systems and instruments in order to provide an intelligible basis for design, production, quality assurance, and general test purposes.

SUMMARY

This project dealt with the measurement, analysis, representation, and simulation of shock accelerations in selected artillery and mortar fire control. Objectives of the project were as follows:

(1) Provide a more rational means for selecting realistic test procedures and updating specifications.

(2) Provide design information useful in the event of field malfunctions and as a basis for modifications and future designs.

(3) Provide a source of information for dynamic analysis of fire control systems.

(4) Provide a means of judging production quality and workmanship.

(5) Provide a stimulus for continued efforts in understanding the shock environment and seeking optimum shock resistant design.

Piezoelectric accelerometer pickups were placed at the base attachment of the fire control instrument and near critical components, such as counters and lasers. Various combinations of elevations and azimuth directions were employed in the firing test program. Maximum explosive charges were used in order to produce the most severe firing conditions.

Firing tests were conducted at Jefferson Proving Ground. Each weapon was emplaced on undisturbed soil in a manner similar to its actual tactical use. Shock signals were transmitted to the Frankford Arsenal Mobile Instrumentation Laboratory via cable from the weapon to the vehicle.

Data collected was then reduced to a shock spectrum through compilation of the maximum responses individual systems would have when subjected to the shock time history. This approach has been used to successfully define shock environments and hence design specifications for equipment and structures to withstand earthquakes, underwater mine explosions, and aircraft landing impact.

The last task accomplished in this project was to specify a shock test specification to simulate the environment as presented in the shock test spectra previously developed. Of the three historical methods of specifying environmental shock specifications (specifying a shock machine, a shock motion time history, and a shock frequency spectrum), it was decided to specify a shock motion time history in accordance with MIL-STD-810. A half-sine pulse shock test was specified for fire control equipment because it can be obtained on a standard shock test machine with the use of reusable elastic impact pads. Figure 1 contains the suggested half-sine shock tests for the fire control equipment analyzed in the execution of this project.

Weapon	Equipment	Half-Sine Pulse Acceleration (g's)	Half-Sine Pulse Duration (milliseconds)
M110 Howitzer	M115 Panoramic Telescope and M137 Mount	75	3
	M15 Quadrant*	100	2
	M116C Elbow Telescope and M138 Mount	60	6
M109 Howitzer	M117 Panoramic Telescope and M145 Mount	75	5
	M15 Quadrant	100	2
	M118 Elbow Telescope and M134 Mount	75	6
M102 Howitzer	M113 Panoramic Telescope and M134 Mount	100	4
	XM114 Quadrant	150	2
	XM114 Elbow Telescope	130	5
M29 Mortar	M53 Sight Unit	100	2

* The test specification for the M15 Quadrant is dictated by the more severe firing environment of the M109 Howitzer.

Figure 1 - Suggested Half-Sine Shock Tests for Fire Control Equipment

BENEFITS

The benefits of this project include the capability to realistically specify the shock and vibration level imposed by selected gun systems on fire control instruments. Data shown above will be useful to procurement specification writers and manufacturers of fire control devices in as much as it will help to prevent overdesign and excessive testing.

IMPLEMENTATION

Shock and vibration test procedures and specifications were incorporated into Technical Data Packages for artillery and mortar fire control items such as the M551, M728, and M60 Fire Control Systems.

MORE INFORMATION

Additional information on this project is available from Mr. Nate Scott, ARRADCOM, AV 880-6430 or Commercial (201) 328-6430.

Summary Report was prepared by Alan L. Peltz, Manufactuaring Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 675 7555 titled, "Dynamic Pressurization Acceptance Testing of Slide Block Breech Mechanisms" was completed in September 1978 by the US Army Armament Materiel Readiness Command, Watervliet Arsenal, at a cost of $83,700.

BACKGROUND

The Slide Block Breech Mechanisms functional and proof production acceptance testing is currently performed at a proving ground by live firings. This testing is both time consuming and costly. If this production acceptance testing could be simulated at Watervliet Arsenal, the cost and time would be reduced substantially.

SUMMARY

The objective of this effort was to design, fabricate, and test a Slide Block Breech Pressurization Production Acceptance testing equipment to simulate the functional and proof testing employed at Watervliet Arsenal. The results of this effort produced a gymnasticator acceptance testing simulator. see Figure 1.

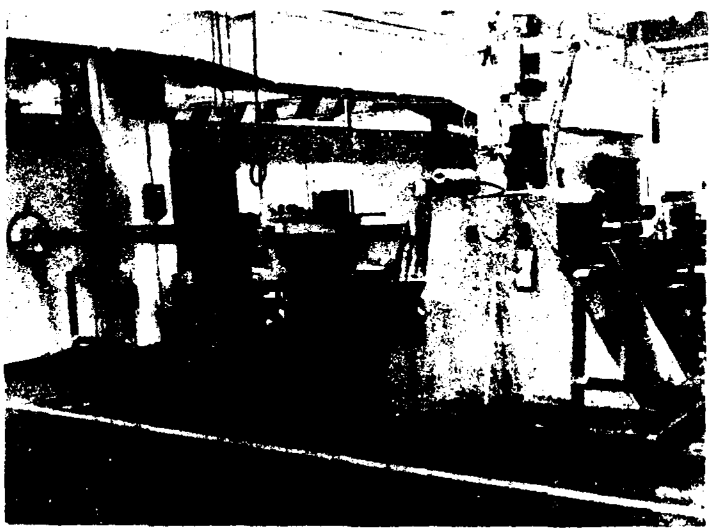


Figure 1 - Slide Block Breech Gymnasticator

The breech mechanism is placed in this gymnasticator. Then an empty shell case is loaded into the breech and the gymnasticator is cycled. The operator visually observes the extraction process and the locking of the extractors. After the gymnastication and pressurization cycle, a tear down inspection is performed where abnormal wear or breakage is detected. This system has the capability to test any case loaded breech mechanism with pressures up to 100,000 psi by changing the stub tube.

BENEFITS

The primary benefit realized by the Army from this project was the capability to simulate the slide block breech mechanisms production acceptance testing. This simulated acceptance testing has reduced the live firing requirements by 75%. The average saving realized by this simulation method is $245 per unit. The projected ten year savings is $565,000. A follow-on MMT project, 679 7555, has been initiated to provide improved instrumentation that will increase the simulator reliability. This instrumentation will reduce the live firing requirement by 86%.

IMPLEMENTATION

This Slide Block Breech Mechanism Dynamic Pressurization Acceptance Testing simulator was first used as a production acceptance test method in January 1978 at Watervliet Arsenal.

MORE INFORMATION

To obtain more information, contact the project officer, J.M. Paine, AV 974-5075 or Commercial (518) 266-5075.

Summary Report was prepared by Delmar W. Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

METALS

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 173 6673 titled, "Precision Forging of Spiral Bevel Gears" was completed by the US Army Aviation R&D Command in October 1977 at a cost of $354,000.

BACKGROUND

High speed, high capacity, spiral bevel gears, such as are used in helicopter transmissions, are very expensive. When this project began, the potential for cost reduction based on further refinement of the existing process was limited. A new approach was needed to significantly improve manufacturing costs without sacrificing load capacity or reliability. The application of precision forging technology held the promise of fulfilling these criteria.

SUMMARY

This project investigated the feasibility of utilizing precision forged spiral bevel gears in a helicopter transmission application. The test gears used in this program were identical in geometry and material to current items in the CH-47C helicopter engine transmission.

The total manufacturing process, including forging, die design, and die fabrication was studied. The demonstration of this new approach to gear manufacture involved the preparation of a precision die using an EDM electrode and several design cycles to arrive at the required dimensional results. Figure 1 depicts the billet, preform, and finish forging ready for finish grinding of one of the two mating gears. Figure 2 shows a comparison of the production methods for the current process and the new precision forging process.

After the process development was completed, gears were finished from the precision forgings. Metallurgical analysis of these confirmed that favorable grain flow in the tooth sections was achieved and case and core properties were to specification. Limited single tooth fatigue testing demonstrated that the forged teeth were at least equivalent to cut teeth. A comparison with cut gear costs showed the forged gears to be about eleven percent cheaper.

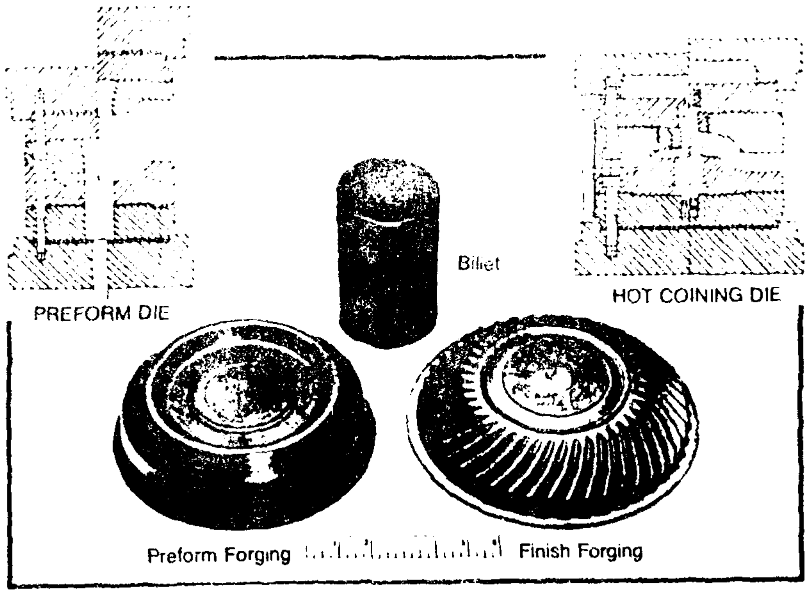


Figure 1 - Two-hit forging process sequence for precision forging spiral bevel gear having 43 teeth and 8,722-in pitch diameter.

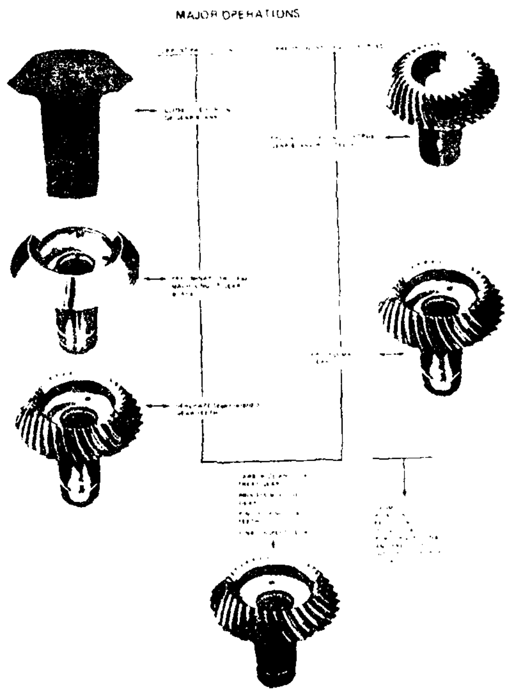


Figure 2 - Comparison of production methods for Spiral Bevel Gears.

BENEFITS

A new process for the manufacture of high speed, high capacity gear systems was developed. This process was shown to be economically feasible and developed a product that is thought to be mechanically superior.

IMPLEMENTATION

The processes developed in this project are practical and readily available to production. Flight testing and qualifying the process for FAA and other regulations is required before implementation can occur.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Harry L. Moss, AV 693-1625 or Commercial (314) 268-1625.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 174 8129 titled, "Columbium Alloy Turbine Engine Components" was completed by the US Army Aviation Research and Development Command in December 1977 at a cost of $200,000.

BACKGROUND

There is a continuing need to improve operating efficiency of turbine engines by increasing operating temperatures. Use of columbium alloys as turbine vane materials would allow increases in operating temperatures significantly above 2000^{o}F.

There are two fundamental problems encountered in the use of columbium. One is the need for providing a sufficiently effective coating to prevent oxidation of columbium at the operating temperature. The second problem is the difficulty in obtaining the desired shape at a reasonable cost. Use of the precision casting technique for casting blades and vanes had a revolutionary effect on the economics of turbine engine manufacture in more traditional materials. Application of the precision casting process to production of columbium airfoils was anticipated to offer similar economic advantages when compared to other fabrication methods.

SUMMARY

Advances in coating technology were made as a result of programs by two contractors and by some supportive work by AMMRC. The Solar Division of International Harvester Company and TRW Inc. were awarded contracts to develop improved processing techniques for depositing the NS-4 coating on columbium alloys. The NS-4 coating consists of depositing a vacuum sintered modifier layer and then siliciding the modifier layer. Currently, modifier layer is deposited by manual dipping in a slurry and siliciding is accomplished by pack cementation. One contractor investigated the Solar NS-4 as a protective coating. The selection of the NS-4 coating for this investigation was based on a demonstrated 1000 hour protection capability and very reproducible performance. Both spraying and dipping of modifier were evaluated. Coating of internal surfaces by dipping was not as reliable as the spraying of external surfaces but many specimens survived 500 hours of cyclic exposure. Dipping tends to leave edges and corners thin. Overall, the program demonstrated the excellent potential of the NS-4 coating in protecting the SU-31 alloy, both sheet and cast.

The second contractor investigated an electrophoretic process for depositing the modifier layer and a chemical vapor deposition process for siliciding the modifier layer. Electrophoretic deposition from both water-base suspensions and isopropanol-nitromethane suspensions were investigated. Initially, deposits were made from the waterbase suspensions using a constant applied potential. Gases resulting from electrolysis of the water produced large numbers of defects in these deposits. Additional deposition trials were made with the waterbase suspensions in which the applied potential was pulsed such that the polarity was reversed on alternate pulses. Using this technique, the defects could be minimized but not completely eliminated in deposits made from waterbase suspensions.

Efforts were then directed towards developing parameters for electrophoretically depositing the modifier layer from isopropanol-nitromethane suspensions. Satisfactory electrophoretic deposits were obtained from this process. Parameters were developed for depositing nominal modifier layer thicknesses of 2.0, 3.5, and 5.0 mils. Deposition times of up to ten hours at a temperature of 2300°F were required to produce minimal silicon contents in the modifier layer.

Rem Metals Corporation was awarded a contract to establish a more complete characterization of columbium investment castings and to further expand the state-of-the-art. The program was carried out in two phases. In Phase I, test specimen castings were produced for comparison of properties, structure, etc. of four columbium alloys which are potentially useful in the investment cast form. Following this limited evaluation and comparison of the alloys, Phase II was conducted. This included the selection of one alloy for further investigation including casting of a typical vane configuration. With the exception of a melt-initiation problem with C-129Y, the four alloys, C-103, SU-31, Cb-752, and C129Y are very similar with respect to castability, fluidity, metal flow, and feeding characteristics. More detailed investigation of C-103 revealed a very good response in mechanical properties to heat treatment. Airfoil castings can be produced with an internal core and with a wall thickness as low as 0.040 inches; see Figure 1. The parameters established under the FY74 program for coating and casting techniques will be further directed at the problem of showing that a cast and coated columbium alloy nozzle can be produced commercially. The goal of the follow-on FY75 effort is to demonstrate that a cast and coated turbine engine nozzle is suitable for sustained operation at metal temperatures above 2000°F, and that the casting approach is the most economical.

BENEFITS

The development of columbium casting and coating technology will provide advanced components permitting designs which will increase specific horsepower and reduce fuel consumption in turbine engines. The benefits of this project will occur when Phase II (i.e., Project 175 8129 is completed.)

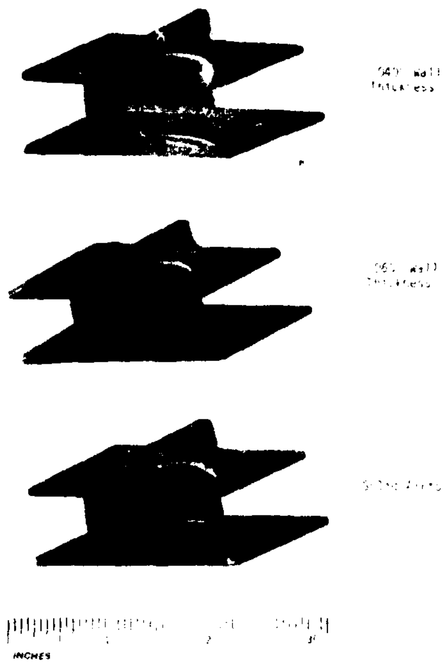


Figure 1 - Investment Cast Columbium C-103 Turbine Vanes

IMPLEMENTATION

The results of this project are being implemented in the follow-on project 175 8129.

MORE INFORMATION

Additional information may be obtained from Mr. Randy Gutscher, AVRADCOM, AV 698-6476 or Commercial (314) 268-6467. Reference Report No. AMMRC CTR 75-25 titled, "Investment Casting of Columbium Alloys" dated Oct 1975; Report No. AVSCOM 76-39 titled, "Coating Processes for Columbium Alloys" dated Sep 1976; and Report No. DRSAV 76-17 titled, "NS-4 Coating Process Development for Columbium Alloy Airfoils."

Summary Report was prepared by Robert S. Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 472 4319 and 474 4319 titled, "Forged Powder Metal Preforms" were completed by the US Army Tank-Automotive Research and Development Command in July 1975 and July 1976 respectively, at a cost of $225,000 and $150,000, respectively.

BACKGROUND

A prior Manufacturing Methods and Technology project conducted by Rock Island Arsenal showed that a production process consisting of hot forging a preform, made by conventional powder metallurgy techniques of pressing and sintering, could produce relatively simple geometry parts having wrought material properties. These two projects were undertaken to extend this technology to more complex shapes like gears.

SUMMARY

This effort was to establish the processing parameters for hot forging powder metal preforms to produce differential pinion and side gears for the M151 utility vehicle. Additionally, those parameters were to be verified through a pilot production run and field testing of the gears to determine their suitability for military use. Figure 1 shows the finished forged powder metal gears.

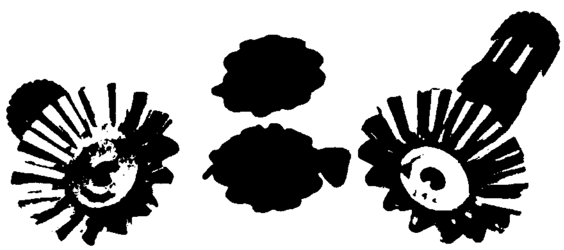


Figure 1 - Finished Gears Produced by Forging Powder Metal Preforms

For these gears, a simple preform geometry was selected so that extensive metal flow would be obtained in reaching complete die fill and full density. The pinions were produced as net shape forgings requiring only the finish machining of a chamfer on one end. The side gears were formed by a one-blow combination of extrusion and forging. Machining was required on the back face, shaft, and outside diameter, but the gear teeth were used as forged. Both the gears and pinions were forged from 4620 steel powder and were subsequently carburized.

Preform weight control was critical because machining was to be minimized. Also, the preform density was critical because densities below 83 percent resulted in cracking on the tooth tips during forging. Proper die fill for good tooth form was controlled by the preform shape. These preforms were sintered under an atmosphere of hydrogen plus one volume percent methane at 1204°C for one hour. Prior to forging, the preforms were heated to 1204°C; the dies were heated to 200-325°C and spray lubricated with graphite in water. The side gear was forged at 345 MPa and the pinion at 552 MPa, both on a hydraulic press.

A total of 300 gears were produced for evaluation. Part of the evaluation included field tests where gear sets were mounted in seven M151A2 1/4 ton trucks and tested at the Yuma Proving Grounds. Four sets were dismantled and inspected after 10,000-12,000 miles and three sets after 20,000-22,000 miles. After the conclusion of this testing, the gears were judged to be suitable for vehicle application. Discrepancies experienced in the bearing patterns of the teeth were determined to be correctable by refinement of forging die dimensions.

BENEFITS

The economic advantages of P/M processing for these gears lie in the efficient use of material and reduced machining costs. The powder metal forging process uses 90 percent or better of the starting material and considerable material cost reductions are possible for large quantities of gears. Based upon a production lot of 200,000 units, cost savings of 23 percent for the side gear and 35 percent for the pinion are projected.

IMPLEMENTATION

Due to the discrepancies in the bearing patterns encountered during the field tests, the gears did not meet the standards of the M151 Vehicle Systems Manager. Sufficient funds for additional forging trials and field testing were not available to convince the Project Manager that these test results did not reflect negatively upon the process or components.

MORE INFORMATION

More information is available from Dr. J. Chevalier, TARADCOM, Warren, MI AV 273-1814 or Commercial (313) 573-1814. Reference TACOM Technical Report numbers 11960 and 12151.

Summary Report was prepared by Gordon B. Ney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 472 4363, 473 4363, and 474 4363 titled, "High Temperature Homogenization of High Strength Steel Forgings and Castings" was completed by the US Army Tank-Automotive Command in June 1975 at a total cost of $325,000.

BACKGROUND

There are problems in the procurement of high-strength cast steel critical components. The components do not consistently meet ductility and toughness requirements of the specifications. This results in high scrap losses. The specific ductility and toughness for a given strength level are required to insure the desired service performance and life cycle.

The purpose of this program was to establish industrial processing technology for high temperature (2350°-2500°F) thermal treatment of critical weapon system components that require superior properties. The project was to generate the necessary in-process specifications and quality assurance engineering data required for procurement purposes.

SUMMARY

This project was conducted in three phases. Phase I was a coordinated high temperature homogenization effort that established the effectiveness of the treatment. The improvement was based on the increase in production reliability and hardness ductility ratios at required hardness levels for critically stressed components such as roadwheel arms, sprockets, and track shoes. These type components were processed and tested at the appropriate government installations. Process technology was determined for each type component.

The Phase II homogenization effort was directed toward establishing the optimum homogenization cycles for various thicknesses of cast armor. Armor plates were cast, test-size machined, and heat treated for ballistic, metallurgical, and mechanical property tests to be conducted later in the program. Planned variations in time and temperature cycling for different thicknesses of armor castings were conducted as a means of establishing the treatment criteria for full-size armor plates.

Phase II consisted of ballistically testing the homogenized heavy armor sections which were heat treated during Phase II. Metallurgical and physical test data was also acquired. The objective of this phase was to determine the overall effectiveness and the economics associated with high-temperature homogenization cycle for production quantities of items for tank applications. Evaluation of the test results showed that the desired objectives of the effort could not be achieved. Therefore, the remainder of the program was cancelled. A considerable amount of R&D effort is required before MMT can adapt the high temperature homogenization concept to production quantities.

BENEFITS

Due to increasing costs of fuel and little improvement in the physical characteristics of cast preforms, this project was considered economically infeasible.

IMPLEMENTATION

Due to failure to achieve the program objectives, the MMT effort was not implemented.

MORE INFORMATION

Additional information may be obtained by contacting Mr. G.B. Singh, AV 273-1758 or Commercial (313) 573-1758.

Summary Report was prepared by Robert S. Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 574 6211 and 575 6211 titled, "Sintered Steel Preforms for Working into Fragmenting Type Shell Bodies" were completed by the US Army Armament Research and Development Command in December 1975 and December 1979, respectively at a total cost of $390,000.

BACKGROUND

Limited research and development work had shown that forged carbon steel powder metal preforms had fragmentation characteristics equivalent to high silica steels. If the production procedures could be established for manufacturing mortar bodies using powder metal preforms, a cost savings could be obtained by substituting a less expensive raw material.

SUMMARY

The objectives of these projects were to demonstrate through pilot production runs that powder metal preforms could be adapted to the current methods of producing fragmenting type mortar projectiles. The first project was to demonstrate that powder metal preforms could be introduced into the standard cold extrusion sequence. The 60mm M49A2 mortar shell was used because tooling was already available. A process was established and mortar bodies were produced from 1040 powder metal preforms. These mortar bodies had mechanical properties exceeding the minimum specified (45 ksi yield strength and 12 percent elongation). Twenty of the mortar bodies produced were subjected to pit fragmentation tests and the results showed that these bodies were at least as good as the conventional cold formed AISI 1340 mortar bodies.

In the second project, the processes required to manufacture the new 60mm M720 mortar shell bodies were established. This meant adapting the powder metal preforms to two different conventional processing sequences. One is the cold extrusion process and the other is the hot cup-cold coin process.

Using the all cold extrusion process, preforms having the same cylindrical shape as the wrought counterpart but weighing less (4.2 vs 4.5 lbs) were produced by standard powder metallurgy techniques of pressing and sintering. The preforms were then processed through the normal sequence of sizing, backward extrusion, coining, forward extrusion, and nosing operations with in-process anneals after the sizing and backward extrusion operations, see Figure 1.

Figure 1 - Sequence in Cold Forming a Sintered Steel 60MM XM720 Mortar Shell Body

Mechanical properties of the sintered steel bodies were slightly lower than the minimum established for the wrought AISI 1340 steel bodies. However, the mechanical properties are sufficient to meet the launch stresses. Fragmentation behavior, as evaluated by pit fragmentation testing, was equivalent to bodies produced from wrought 1340 steel.

In the hot cup-cold coin process, cylindrically shaped preforms weighing 3.4 lbs were introduced into the normal processing sequences of upset and hot backward extrude (1600°-1800°F) followed by the cold coining, drawing and nosing operations. Preforms produced from an atomized iron powder were successfully formed into 60mm M720 bodies. Mechanical properties were again slightly lower than the minimum established for the wrought AISI 1340 bodies but sufficient to meet launch stresses. Several of the bodies were tested for lethality (panel tested) and fragmentation (pit tested). The results showed no significant difference between the bodies produced from sintered steel and wrought 1340 steel.

BENEFITS

These projects have provided processing and design data for the use of sintered steel preforms in the current production practices for making fragmenting type munitions. Benefits could result from providing an alternate starting material which is cheaper and provides fragmentation behavior at least equivalent to wrought AISI 1340 steel bodies. In the case of the 60mm M720 mortar, current estimated cost is $4.89 per body while the best engineering estimate for the sintered steel mortar body is $4.78. This represents a potential savings of approximately two percent.

IMPLEMENTATION

When these efforts were initiated, the price of iron powder was significantly lower than wrought steel. However, now the price of iron powder is four cents a pound more expensive than the wrought steel. This has significantly diminished the originally envisioned cost savings. Furthermore, the production rate for mortar shells was significantly higher when the program began. At that time, a second plant was being planned to meet the production requirement. However, now the reduced mortar production rate is within the production capacity of existing facility and during the life of this project, that facility was modernized for the production of wrought mortar bodies.

The diminished savings due to increased iron powder prices and reduced production requirements have reduced the incentive to implement the results of these projects, particularly since an expensive safety qualification test program is still required to qualify the powder metal process as an alternate production process.

MORE INFORMATION

Additional information can be obtained by contacting Dr. J. Burlingame, AV 880-2596 or Commercial (201) 328-2596.

Summary Report was prepared by Gordon Ney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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MANUFACTURING METHODS AND TECHNOLOGY. PROJECT SUMMARY REPORTS.(U)

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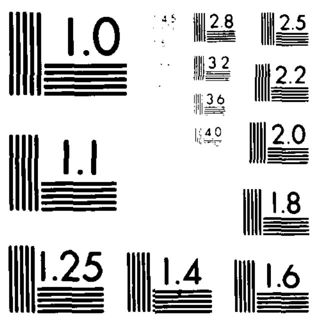

MICROCOPY RESOLUTION TEST CHART
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MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 571 6388 titled, "Production of High Density Tungsten Base Preformed Framents for Warheads" was completed by the US Army Armament Research and Development Command in January 1974 at a cost of $88,000.

BACKGROUND

Research and development work had shown that heavy alloy systems such as tungsten-nickel-iron (W-Ni-Fe) and tungsten-nickel-copper (W-Ni-Cu) having densities of 16 to 18.5 g/cc had a considerable advantage over conventional steel (7.87 g/cc) fragments in ballistic applications where retardation effects and residual mass are significant factors. The research and development work had also shown that commercially obtained heavy alloy fragments demonstrated wide variability in mechanical properties and the commercial processing procedures used were proprietary.

SUMMARY

The objectives of this project were 1) to establish the processing procedures for producing uniform preformed heavy alloy fragments, 2) to establish a pilot line for the production of thirty grain cuboid fragments to varify the processing procedures, and 3) to prepare a purchase description which would enable the competitive procurement of heavy alloy fragments. Several commercially available tungsten alloys were examined for the mechanical property and microstructural effects of various processing parameters. These parameters included sintering time and temperature, cooling rate from the sintering temperature to a temperature below the solidus, and heat treating procedures. Thirty thousand 90N-5Ni-5Fe thirty grain cuboid fragments were manufactured in the pilot production line to varify the processing procedures. From the pilot production run data, a purchase description for tungsten-nickel-iron heavy alloy preformed penetrators (FA-PD-MI-5132, Rev 1) was prepared and has the following major requirements:

Composition

Nickel	- 5.0% ± .2%
Iron	- 5.0% ± .2%
Impurities	- .005% max. each, .1% max. total
Tungsten	- Remainder

Density - 17.00 ± .10 gm/cc

Mechanical Properties

1. Compressive Yield Strength - 80,000 at .2% offset with no visable cracks after testing.

2. Hardware - Average Rockwell C 24 to 26.

3. Ultimate Tensile Strength - 123,000 psi min.

4. Elongation - 15% minimum in one inch gauge section.

5. Microstructure - Uniform distribution of tungsten and matrix material.

6. Finish - as-sintered.

BENEFITS

This project established a purchase description for use in the competitive procurement of heavy alloy gragments.

IMPLEMENTATION

The project was to support the production of SAM-D and Chaparral missile warheads. At the conclusion of this project, a study showed that the steel preformed fragments would be more cost effective for the SAM-D missile. For the last two procurement buys of the Chaparral missile, the purchase description established as a result of this project was modified and used.

MORE INFORMATION

Additional information on this project is available from Mr. W. Seldon, AV 880-4121 or Commerical (201) 328-4121.

Summary Report was prepared by Gordon Ney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 572 6407 titled, "Lead Infiltrated Iron Base Material for Improved Rotating Bands" was completed by the US Army Armament Research and Development Command in June 1974 at a cost of $70,000.

BACKGROUND

Spin stabilized, ammunition projectiles (20 millimeters and larger) require a rotating band whose function is to provide a seal between the projectile and gun barrel and to impart spin to the projectile as it travels the length of the barrel. Rotating bands are attached to the projectiles in one of two ways depending on the projectile wall thickness. Where thickness allows, a knurled slot is cut into the projectile and the gilding metal band is pressed into the slot. Where the thickness is too thin, the band is deposited by the welded overlay process.

Copper is an expensive material which is used in many items. During mobilization, copper becomes a scarce material. Therefore, the Army sought to substitute a lead infiltrated iron base material for those applications where gilding metal was pressed onto the projectile.

SUMMARY

The objectives of this three year effort were to establish processing parameters to make acceptable lead infiltrated rotating bands, to establish a pilot line for producing the bands, to ballistically test the bands for acceptability, and to prepare a description of manufacture to be used in procurement. The FY72 project, the first of three years, was the only project funded.

The project began by establishing the processing parameters required to make rotating bands that would meet the Class 3 band requirements of MIL-R-11073C (MU) Rotating Band Blanks, Sintered Iron. The experimental work showed that the amount of lead that would be infiltrated depended upon the amount of surface connected porosity in the iron-base powder metallurgy preform and the temperature at which the infiltration took place. Surface connected porosity was controlled by the type of iron powder and the compacting load used to fabricate the preform. A minimum infiltration temperature of 1400°F was required to obtain 90 percent of the theoretical lead content for preforms fabricated from an atomized iron powder at 15 to 21 percent porosity and for preforms fabricated from a mill scale iron powder at 8 to 18 percent porosity. However, a temperature of 1800°F was required for preforms fabricated from a reduced ore type powder at 21 percent porosity.

Two small test quantities of 20mm rotating band blanks were produced. One group was produced from the atomized iron powder; the other was produced from the atomized iron powder to which 2.5 percent copper was added to increase strength. Infiltrated densities and mechanical properties are given in Table 1. Both materials had tensile strengths 3,000 to 5,000 psi higher than those specified for Class 3 bands and the percent expansion obtained was nearly three times the required amount. The addition of copper produced a much smaller increase in strength than was expected.

Table 1
Infiltrated Densities & Mechanical Properties

Material	Lead Content (Weight %)	Infiltrated Density (g/cc)	Tensile Strength (psi)	Expansion (%)
Atomized Powder	25	8.3	19,000	14
Atomized Powder plus 2.5% copper	28	8.4	21,500	6

BENEFITS

The processing parameters to make lead infiltrated sintered iron rotating bands which meet the Class 3 band requirements of MIL-R-11073C (MU) has been established. A potential savings of two cents per band in the 20mm size and thirty cents per band in the 105mm size were identified. However, the second and third year funds were not provided and, therefore, the effort was never completed.

IMPLEMENTATION

Continuation and implementation of this effort was hindered because of: a) The Surgeon General's policy which called for minimizing the use of lead in ammunition; b) the ammunition design engineer's reluctance to change from a material that was performing satisfactorily; and c) the belief that plastic rotating bands being developed by the Air Force would replace all metal bands.

MORE INFORMATION

Additional information on this project is available from Dr. John Burlingame, AV 880-2596 or Commercial (201) 328-2596.

Summary Report was prepared by Gordon Ney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 573 6580 titled, "Induction Heat Treating of Projectile Shapes" was completed by the US Army Armament Research and Development Command in September 1978 at a cost of $220,000.

BACKGROUND

The use of atmospheric gas fuel furnaces and salt pots for the heat treatment of projectile bodies is dirty, expensive, and involves various handling operations. The heat treated body must undergo many machining operations, especially in the hardened rear section near the bands. These operations, which must be done upon completion of heat treatment, cause high cutting tool costs. The objective of this project was to provide a reliable, less costly heat treatment system that would allow the rear section of the projectile and the keyways to be machined before hardening, and would eliminate several of the handling operations. Furthermore, the process would use electricity, instead of fossil fuels, as an energy source to eliminate the added expense of holding furnaces overnight or over a weekend and to lower equipment maintenance cost.

SUMMARY

AJAX Magnethermic Corporation was awarded a contract to study and develop a new process. The basic work effort was to design and fabricate experimental induction heat treating machines and to develop the optimum operating parameters to produce acceptable heat treated projectile bodies which meet the minimum end item mechanical property requirements. The work effort was divided into five phases. Phases I and II were to establish induction scan heat treating, operating, and design parameters. This was to be done by heat treating both the 8-in. M509 and the 155mm M483 projectile bodies utilizing an existing laboratory machine. Phase III was to design and construct a three-station scan induction heat treating machine that would simultaneously heat treat three projectile bodies. The scan method of induction heating is a process in which the projectile body is passed through a stationary induction coil, see Figure 1. The portion of the body to be heat treated is encased within the coil and is heated to a preselected temperature. The soak time, the amount of time the heated portion is held at temperature, is dependent upon the speed at which the projectile body is "scanned" through the coil. Phases I, II, and III were worked on concurrently until heat treating problems were encountered with the scan method. The major problem encountered was the inability of obtaining sufficient heat and adequate soak time to complete material transformation primarily in the area behind the welded overlay rotating band. The scan program

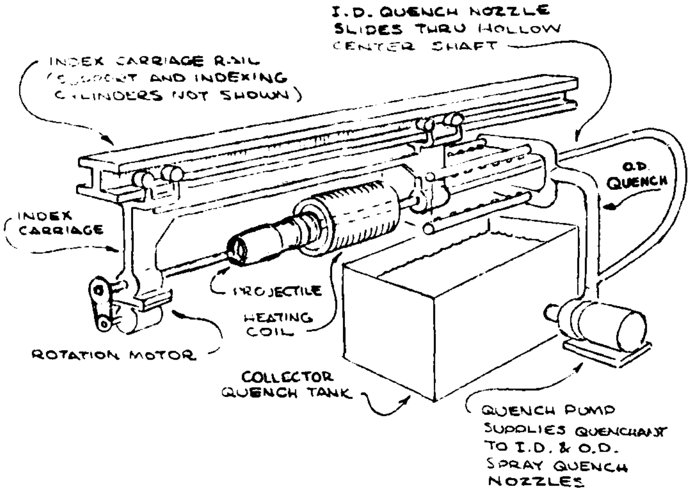


Figure 1 - Scan Method of Induction Heating

was then modified to establish a static type induction heat treating method. This feasibility study was also conducted by AJAX. The static method differs from the scan method in that the entire projectile body is totally encased within the induction coil, see Figure 2.

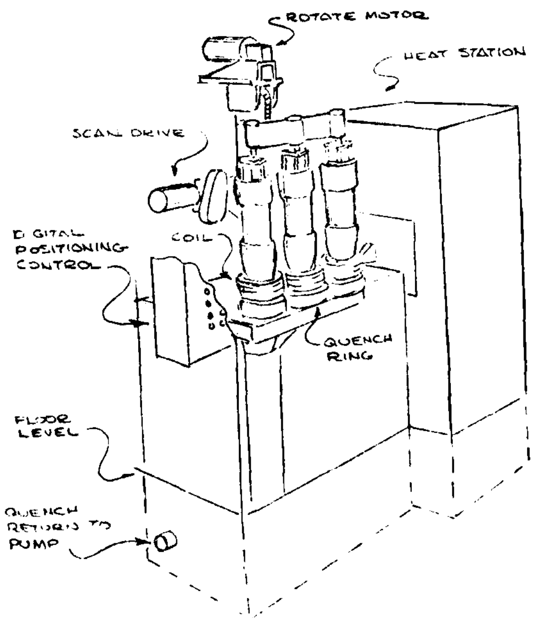


Figure 2 - Static Method of Induction Heating

This allows for simultaneous heating of the entire projectile body to the pre-selected temperature and provides for a more flexible soak time capability than the scan method. The feasibility study was completed utilizing one coil for austentizing and one coil for tempering. The use of the tempering coil for austentizing the projectile bodies proved unsuccessful due to resulting non-uniform temperature profiles. Based on the data developed from the heat treating study, AJAX was requested to submit a proposal to modify the scan machine. The cost to modify the scan machine to a static machine was greater than the original cost of the scan machine and the modified machine would not have provided a production piece of equipment. Therefore, it was decided to complete Phases IV and V with AJAX under the original contract scope of work. In Phase IV, the ability of the scan induction heat treating machine to function in a continuous manner was demonstrated. This was done by heat treating thirty 8-in. M509 and thirty 155mm M483 projectile bodies. Acceptable mechanical properties, hardness patterns, and microstructures were obtained from these test samples.

A final report, induction scan machine operating manuals, and equipment drawings were provided under Phase V.

BENEFITS

Induction heat treating was determined not to be economically cost effective when compared to conventional heat treatment systems.

IMPLEMENTATION

The project results were not implemented even though the ability to induction heat treat the 155mm M483 projectile body by the static method was demonstrated. The conventional heat treat systems will be employed for the 8-in. M509 and the 155mm M483 projectile bodies because induction heat treating was determined to be not economically cost effective.

MORE INFORMATION

To obtain more information, contact the project officer, Mr. Kurt W. Maute, AV 880-2522 or Commercial (201) 328-2522. Reference ARRADCOM Tecnical Report No. ARLCD-TR-78036, dated September 1978.

Summary Report was prepared by Robert Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 672 6786 titled, "Automation of Gun Barrel Bore Chromium Plating Process" was completed by the US Army Armament Command/Rock Island Arsenal in May 1975 at a cost of $70,000.

BACKGROUND

The current method of applying chromium electrodeposits to gun tubes is a manual, batch operation. Each gun tube is racked, unracked, and sized individually, twice during the process. Manual control of hoist and conveyance operation, bath dwell times and amperage control is required. With automation, the art of plating could be replaced by reproducible modern technology. Automation could also be used to handle complicated plating cycles which demand consistent pretreatments and bath dwell times. Therefore, there is a need to establish an automated chromium plating line for processing small caliber gun tubes.

SUMMARY

The objectives of this project were to prepare a purchase description for the procurement of an automated chromium plating system, contract for the purchase of the automated equipment, install and test the equipment, and establish procedures for chromium plating small caliber rifle bores. The experimental work included three process evaluation segments: the electropolish process, the chromium plating process, and the automated process combining the electropolish and chromium plating sequence. The gun tubes used throughout this project were 5.56mm M16 rifle tubes made of Cr-Mo-V steel machined to final dimensions.

The electropolish study was made to determine the rate of stock removal as a function of bath use. The time to remove 1.0 to 1.2 mils per side as a function of bath use had to be determined. Twenty-four 5.56mm gun tubes were electropolished for various time durations. After each electropolish, measurements were made on muzzle end and process time adjusted for succeeding runs. It was observed that a steady-state rate could not be obtained with this sample size. It was necessary to reduce the electropolish dwell times with the number of gun tubes processed.

The chromium plating process was evaluated to determine parameters necessary for obtaining a chromium plate of 1.0 to 1.5 mils per side. Measurements were taken and adjustments in plating time were made to obtain desired thicknesses of chromium deposits. It was determined that a

fifty minute plating time for the automated runs would yield the desired after-plating dimensions.

The automated plating system was procured from the Oxy Metal Industries Corp. The plating line consists of processing tanks, a hoist used to lift and transfer work to various processing tanks, and automated controls. Figure 1 shows the processing sequences.

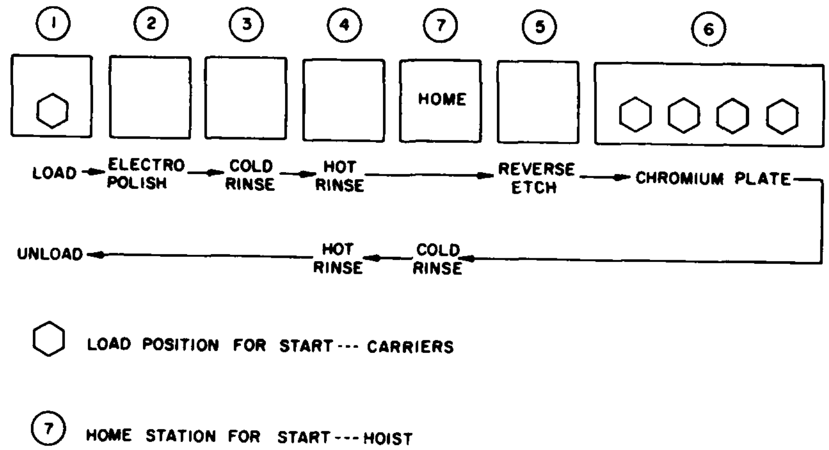


Figure 1 - Automated Plating Line Operation

The process differs from routine chromium plating of gun tubes in that no measurements of stock removal after electropolish are taken during the automated process. The gun tubes are racked with the muzzle-end up in a rotating electrode fixture, see Figure 2.

This fixture consists of lead-tin coated steel electrode and wound with a Teflon rod spacer. The electrode is mechanically rotated with the bore by means of a flexible cable attached to an electric drive motor. The rotating electrode is utilized in both electropolishing and chromium plating operations.

BENEFITS

The benefits resulting from this project include establishing the feasibility of automated plating of small caliber gun tubes which would result in a significant cost savings.

IMPLEMENTATION

The automated chromium plating of small caliber gun tubes cannot be implemented to full scale production until such time that buy quantities are sufficient to make the process cost effective.

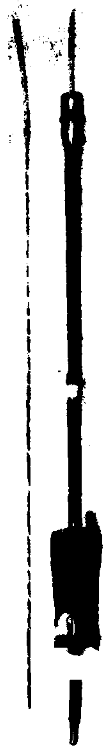


Figure 2 - Plating Fixture with Gun Tube Attached and Rotating Electrode (shown separately)

MORE INFORMATION

Additional information may be obtained from Mr. John D. Rowe, RIA, AV 793-5504 or Commercial (309) 794-5504. Reference RIA Report No. EN-79-04 titled, "Automated Chromium Plating Line for Gun Barrels," dated September 1979.

Summary Report was prepared by Robert Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 672 6809 titled, "Reduction of Embrittlement of High Strength Steel in Metal Finishing Processes" was completed by the US Army Armament Command in November 1974 at a cost of $30,000.

BACKGROUND

Quality control standards are inadequate in many areas of embrittlement problems. The requirements for certain procedures for hydrogen embrittlement relief of high strength or spring steels after application of a protective finish are often misunderstood with the result that the contractor requires a waiver. Most of the specifications are poorly defined or are ambiguous because insufficient data is available to adequately describe the problem conditions. The requirement for baking for hydrogen embrittlement relief can increase the production cost considerably, especially if there is no demonstrated need. At the same time, some components are manufactured with finish requirements that produce failures that apparently cannot be remedied by the relief treatments written into the specifications.

Statements of exact needs for baking of embrittled parts can be supported in production processes by application of simplified tests. Several tests using easily made specimens are available for use but have not been thoroughly evaluated against standard procedures. This project work was to apply these techniques for production use.

SUMMARY

This effort began with FY69 funds and was directed toward the establishment of embrittlement behavior of high strength steels in the zinc phosphating process. Results of this work showed a considerable variability in embrittlement for various types and hardness conditions of the steel used. Efforts were continued with FY71 and FY72 funds to complete the investigation of the zinc phosphating process and also to investigate the electroless nickel and zinc plating processes. The results are summarized below.

<u>Zinc phosphating</u> - Steel specimens having R_c 30 hardness did not require embrittlement relief. Some specimens of R_c 40 hardness failed stress rupture tests when no relief measures were applied. The hydrogen embrittlement relief procedure specified in the military specification requires an eight-hour bake at 210-225^oF or 128 hours at room temperature. These procedures assured relief for all steel specimens of R_c 40 hardness. These methods of hydrogen embrittlement relief, however, did not assure relief of R_c 50 hardness specimens. Abrasive blasting increased the effectiveness of the specified relief

treatments. Vacuum relief apparently does not increase the rate of hydrogen removal appreciably. Specimens held in vacuum (10^{-4} Torr) for four hours at room temperature all failed the stress rupture tests. Four hours in water at 210°F gave some embrittlement relief, but the specimens still failed the 200 hour stress rupture test.

Electroless nickel plating - All specimens were in the R_c 48-52 hardness range. Without relief treatment, all acid electroless nickel plated specimens failed within 0.3 hours. However, all responded well to specified relief bake treatment (375°F for three hours). When the bake procedure was reduced to one hour at 300°F, one out of five specimens failed. With one hour baking at 350°F, there were no failures even after maintaining a load on the testing specimens in excess of 500 hours.

Zinc electroplating - Specimens of R_c 30 and R_c 40 did not require embrittlement relief. Without relief, all specimens in the range of hardness R_c 48-51 broke on loading. With a three-hour bake at 350°F (military specification), all broke within 0.1 hours. When the bake temperature was increased to 400°F for three hours, all five specimens broke within 0.3 hours. Using a 24-hour bake at 375°F resulted in specimens fracturing between 0.2 and 2.7 hours. Increasing the bake time to 72 hours and the temperature to 400°F did not assure relief from hydrogen embrittlement although the time to fracture was increased to as long as 185 hours.

Therefore, standard treatments can be applied to assure hydrogen embrittlement relief for standard steel of hardness R_c 40 or below. For steels R_c 50 and above with phosphate or zinc plate finishes, relief could not be assured by standard or experimental measures. For electroless nickel plated steel of R_c 50, standard or specified bake out treatments were found to be effective in relieving hydrogen embrittlement.

BENEFITS

It is anticipated that cost reductions of 10% to 25% of processing expense will be accomplished by eliminating hydrogen embrittlement relief when it is not needed. By requiring a proper relief treatment where needed, the prevention of failures and consequent increase in component reliabilty will also result.

IMPLEMENTATION

Information generated from this project is available for use in revision of specifications in engineering and in quality control.

MORE INFORMATION

Additional information on this project is available from Mr. J. DiBenedetto, AV 793-4584 or Commercial (309) 794-4584.

Summary Report was prepared by Robert S. Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 671 7042 titled, "End Item Manufacturing Process Guide" was completed by the US Army Armament Material Command in November 1975 at a cost of $250,000.

BACKGROUND

The introduction of new manufacturing methods and technology at Watervliet Arsenal was basically dependent upon the creative talents of a small group of individuals. Drawing upon their broad range of experience, current methods were observed and attempts were made to improve the manufacturing process by introducing new technologies. Target areas were chosen almost at random and reflected personal preferences. This led to a less than optimum allocation of resources.

SUMMARY

The purpose of this project was to develop a systematic procedure for identifying manufacturing inefficiencies. The objective was to prepare an end item manufacturing process guide specifying the interactions between end items, materials, and processes. The guide would provide an aid in determining which manufacturing elements or areas offered the greatest potential for improvement. The desire was for an analytical framework that could be used for delineating, evaluating, documenting, and ranking those aspects of weapons manufacture which lend themselves to improvement.

To accomplish this task, it was necessary that the implementation of the guide incorporate time and cost data in a rather unconventional way. This was primarily due to the desire to utilize current data in a manner precluding concentration on the details of current technology. The latter concern was accommodated through development of the concept of a "functional classification scheme (FCS)." By describing each current manufacturing activity or process in terms of the function being performed, it was possible to assess the current cost of performing the functions required to produce a given end item without reference to the methods employed. By then comparing these costs, both within and among the end items, high cost functions would be pointed up for further manufacturing research.

Depicted in matrix format, "Process/Functional Categories" form the rows and "Functional Subsets" form the columns of the FCS. Each element in the matrix will take on different values dependent upon the characteristics of the operation being performed. Categories chosed for the Process/Function include: a) Metal Removal, b) Metal Forming, c) Metal Joining, d) Metal Treatment/Finishing, and e) Measurement/Inspection. The Functional Subsets include I) Size and Shape of the Item, II) Extent of Operation, III) Purpose of Operation, IV) Character of Operation, and V) Other. A particular function is defined by selecting one parameter from each of the Functional Subsets forming an alpha-numeric code.

The FCS is similar in concept to group technology classification systems in that it describes a part in general terms. The difference is that where the objective of group technology is to classify similar parts into families in order to improve machine utilization, the objective of the functional classification scheme is to identify commonality in operations on the same part in order to better group them on several machines used to manufacture the part.

Using the FCS, a framework was created that provided a set of informational reports that would quantify, in a technology independent manner, the advantages, disadvantages, and possibilities inherent in the existing production processes for any given end item. These informational reports (computer generated) comprised of nine interrelated tables, allow the analyst to determine precisely those elemental operations in the overall process which a proposed technological advancement might affect. The reports are listed in Table 1.

Table 1 - Computer Generated Reports

Number	Name
1	Per Unit Function Cost by End Item
2	Function Costs for a quantity of - units
3	Labor Concentration by End Item Surface
4	Process Candidates for Combination
5	Process Candidates for Combination (regardless of action surface)
6	Per Unit Function Time vs. Process
7	Facilitating and Correcting Operations Time Listing
8	Facilitating and Correcting Operations Time Listing (Explosion)
*9	Production Mix Feasibility Analysis

*Manually Prepared

BENEFITS

The End Item Manufacturing Guide is a viable means for analyzing a manufacturing process to determine areas in need of improvement. The guide will assist in the following tasks: a) development of specifications for new technology, b) evaluation of the feasibility of attaining high volume production mixes, such as mobilization quantities, c) cost and throughput comparison of alterntive production methods, d) rate of return analysis, and e) analysis of various end items' competition for processing resources.

IMPLEMENTATION

The Guide is a detailed breakdown of the system and of the reports and analysis needed to implement it. The Guide is being used at Watervliet Arsenal to pinpoint areas of high cost manufacturing.

MORE INFORMATION

A final technical report titled, "Development of an End Item Manufacturing Process Guide" dated October 7, 1974 describes the Reports and Functional Classification code in detail. Contact Mr. G. Spencer, Watervliet Arsenal, AV 974-5319 or Commercial (518) 266-4201.

Summary Report was prepared by J.H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 673 7124 titled, "Effect of Electroless Nickel Process Variables on Quality Requirements" was completed by the US Army Armament Command/Rock Island Arsenal in November 1974 at a cost of $40,000.

BACKGROUND

The rapidly expanding use of electroless coatings on plastic items for consumer products has resulted in an increased interest in electroless processes. However, these coatings are very thin and adhesion is often related to complete encapsulation of the item. Definition of the electroless nickel process in terms of adhesion for heavy coatings will provide engineering relibability. It is projected that electroless nickel could be readily substituted for chromium in many applications for wear and erosion resistance. Electroless nickel has been widely accepted as a means for producing a uniform, relatively pore-free coating that will deposit evenly on difficult to reach complex configurations.

SUMMARY

This effort involved the study of electroless nickel solutions to establish the effect of process variables on the deposition of heavy coatings of electroless nickel, and to determine the conditions that would produce maximum adhesion. The work was directed toward the establishment of process controls for electroless nickel for engineering reliability. The operating variables were to extend to levels outside the normal operating ranges.

The types of electroless nickel baths evaluated were the acid type of Brenner, acid sulfamate, alakaline sulfamate, and three proprietary types. These baths were operated under various conditions and compositions. The process parameters measured included operating temperature and pH, deposition rate, metal distribution, and heat treatment time and temperature. The hardness and phosphorus contents of the deposits were also determined.

Extensive hardness data were obtained for deposits with 2.8% to 12.6% phosphorus as-plated and after heat treatments at 100, 200, 400, and 600°C. The data showed considerable variation in the effects of heat treatment depending on the bath composition and the phosphorus content of the deposit as well as the duration and temperature of heat treatments. In general, deposits with more than 7.5% phosphorus have about the same hardness, and those with less phosphorus are somewhat harder; see Figure 1.

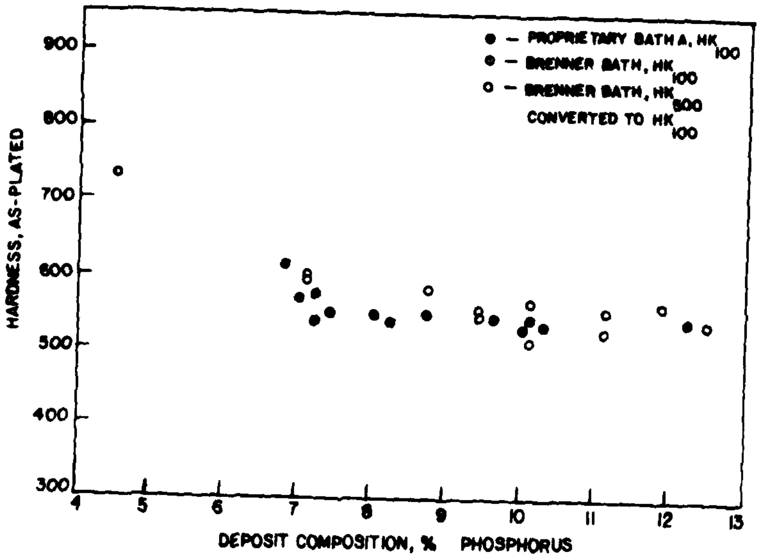


Figure 1 - As-Plated Hardness as a Function of Phosphorus Content in the Deposit

Deposits that are low in phosphorus are substantially hardened by a heat treatment at 200°C; however, as the phosphorus content increases, the effect becomes less and is negative for some deposits with more than 10% phosphorus. The heat treatment temperature for maximum hardness is not fixed at 400°C, but usually falls between 350°C and 425°C and may be as low as 300°C. Heating above 420°C gives hardnesses less than the maximum with the decrease becoming very pronounced as the phosphorus content decreases. Procedures for plating .17 caliber gun bores with electroless nickel were determined. By taking into consideration the phosphorus content of the coating, a range of hardnesses can be predicted and obtained using the proper thermal treatment on the coated item. For heavy build-up work, constant monitoring of the bath parameters is necessary to obtain a coating with a constant predictable phosphorus content.

BENEFITS

The benefits resulting from this project include the establishment of the parameters for electroless nickel plating processes as applied to small arms weapons. Increasing the adhesion and wear resistance of coatings would reduce the frequency of maintenance and this would result in reduced operating cost and inventory requirements.

IMPLEMENTATION

The work performed on this project has been summarized in a technical report. The results of this project are available for implementation and have been recommended for use in production particularly on many hard to plate items where chromium is used as a wear resistant coating.

MORE INFORMATION

Additional information may be obtained from Mr. D.H. Sale, RIA, AV 793-5504 or Commercial (309) 794-5504. Reference RIA Report No. R.RR-T-6-75-73 titled, "Effects of Electroless Nickel Process Variables on Quality Requirements", dated October 1973.

Summary Report was prepared by Robert S. Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 672 7207 titled, "Application of Bore Guidance System to Mid-Caliber Gun Tubes" was completed by the US Army Armament Command in December 1975 at a cost of $75,000.

BACKGROUND

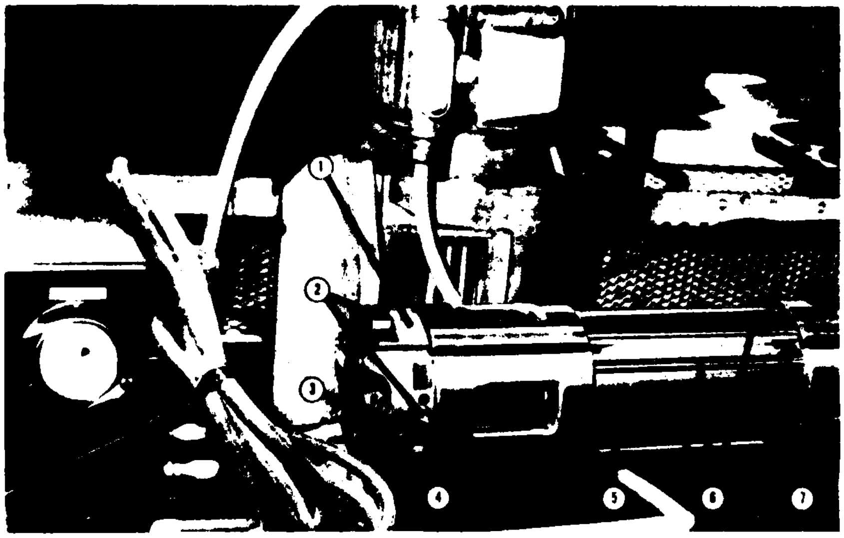
One of the primary bottlenecks of cannon manufacture is the production of an acceptable bore diameter of desired concentricity. This problem is especially prevalent in tubes in excess of 20 feet in length.

Although the methods of producing acceptable bores kept pace as well as could be expected with the introduction of new weapons, often a boring tool would deviate beyond acceptable limits resulting in costly rework or total scrap. Until the development of a runout detection device, there was no satisfactory method of observing the bore axis during the boring operation. The manufacture of these long tubes required skills on the part of both the boring tool maintenance personnel and the boring machine operator.

The machine operator, by observation of chip formation, boring bar deviation, and horsepower consumption, had to decide whether to terminate a boring pass or continue an operation that might result in an unacceptable out-of-round bore.

SUMMARY

The objective of this project was to develop a bore guidance system for mid-caliber gun tubes. It was decided that the bore guidance system for large cannon boring lathes could be adapted to mid-caliber gun tubes through the use of hydrostatic bearings in the boring head. The new guided boring head is shown in Figure 1. Both front and rear support is obtained by the use of hydrostatic bearings. Each bearing has four pockets where hydraulic oil is supplied, thus maintaining an oil film around the complete periphery of the bearing. In the bore guidance head the front and rear supports function independently to allow for correction of the head. The rear support is rigid and acts as a fulcrum from which the boring head guidance is derived. The front support is variable and thereby changes the direction of the head with respect to the rear support and allows the head and tools to move as corrective action is taking place.



1 - Cutter Plate
2 - Inductive Sensors
3 - Cutter Pocket
4 - Front Hydrostatic Bearing
5 - Spacer
6 - Hydraulic Lines
7 - Rear Hydrostatic Bearing

Figure 1 - Guided Boring Head

BENEFITS

The bore guidance system developed by this project has replaced three wood pack boring lathes and has resulted in a straightness deviation of less than .005 inch. This increased accuracy has resulted in fewer problems in obtaining proper stock distribution after boring. Additionally, smaller diameter forgings can be purchased resulting in material cost savings. Cost savings of $565,000 have occurred as a result of these changes.

IMPLEMENTATION

The bore guidance system has been incorporated in the production of M185, 155MM cannon tubes at Watervliet Arsenal.

MORE INFORMATION

Additional information on this project is available from Mr. F.A. Heiser, Watervliet Arsenal, AV 974-5507 or Commercial (518) 266-5507.

Summary Report was prepared by Alan L. Peltz, Manufaccuring Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 673 7253 titled, "Establish Periodic Reversal Plating of Chromium for Improved Properties in Weapons Applications" was completed by the US Army Armament Command in May 1975 at a cost of $100,000.

BACKGROUND

Chromium is usually applied for wear and erosion resistance in weapon applications. Although most chromium coatings are relatively thick (one to five mils) there are many occasions where deposits less than a mil thick would be valuable if corrosion resistance could be improved. Periodic reversal plating techniques have indicated that such improvement is possible in chromium deposition. The periodic reversal technique is commonly used to refine the structure and provide a leveling action in the plating with other metals but has not been used extensively for chromium. The process involves a cycle of plating and deplating, suitably chosen to provide the desired deposit. This work was undertaken to select and establish the conditions for the periodic reversal plating of chromium for production purposes.

SUMMARY

This work was conducted to determine process variables and deposit characteristics and to establish a process technique for periodic reversal (PR) plating of chromium. The PR chromium plating process investigated covered the effects of periodic reverse current and pulsed direct current on the properties and distribution of chromium electrodeposits, see Figure 1. The plating current was reversed for short periods (1/4 - 36 seconds) during the deposition of chromium at various current densities in baths at several concentrations of chromium trioxide. Several chemicals (sodium hydroxide, boric acid, oxalic acid, sodium chloride, and sodium carbonate) were added to the standard bath to further improve deposit distribution during PR plating. Such chemical additions as oxalic acid and sodium hydroxide and the use of lower chromium trioxide concentrations were effective in further improving plate distribution obtained with PR. Distribution ratio (ratio of edge-to-center plate thickness) of approximately 0.9 was obtained on the panels. Screw threads plated with PR resulted in a distribution ratio of 1.3, an acceptable value for this type of geometric configuration. The most uniform deposit thicknesses were obtained in the low concentration baths. Internal diameters, when plated using PR current, required 30% longer times to deposit a given thickness than an identical item plated

without PR at the same current density. The PR plated chromium was darker and did not have the characteristic luster associated with conventional chromium plate. Small but definite improvements in the distribution of chromium deposits were obtained using pulsed dc current. This method involved plating by pulse cycled (PC) dc current. Panels plated by the PC method resulted in a distribution ratio of 1.3 which is significantly lower than the 1.6 value obtained by conventional plating methods.

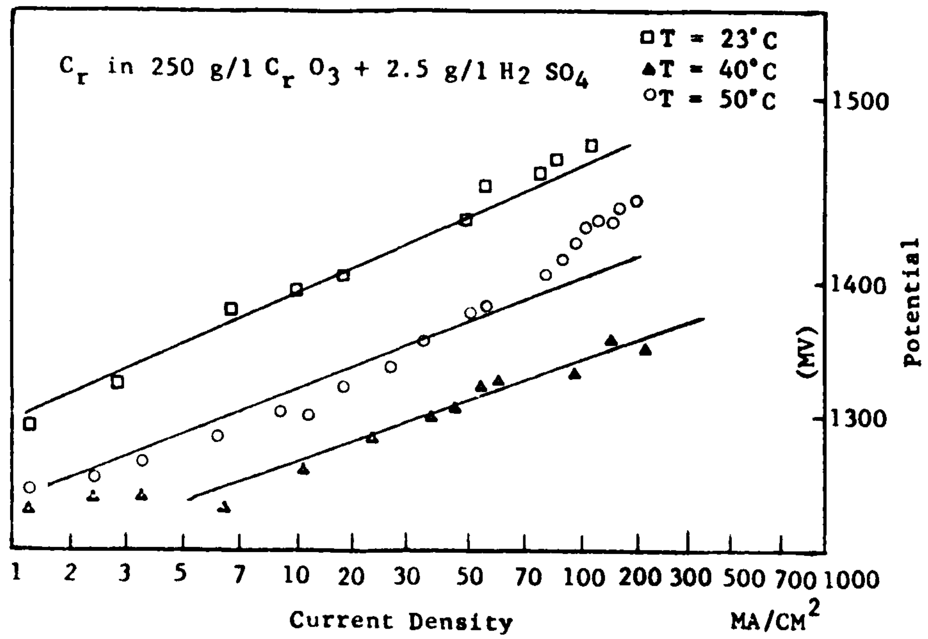


Figure 1 - Curves for the electrolytic dissolution of chromium by reverse current

BENEFITS

Periodic reversal chrome is desirable since it provides a means of depositing chromium with good thickness uniformity on many surfaces. This uniformity eliminates the need for grinding operations to true the surface after chromium plating. The use of pulse cycled plating is an alternate process that will produce coatings having excellent thickness distribution.

IMPLEMENTATION

Although improvements in deposit distribution were shown with PR and PC, the gains are not significant enough to warrant implementation of such power supplies for production chromium plating. Continued development of these processes is necessary, especially as new electronic power supplies are introduced in the industrial market.

MORE INFORMATION

To obtain more information, contact the project officer, Mr. D.H. Sale, AV 793-5504 or Commercial (309) 794-5504. Reference Technical Report No. R-CR-76-030 titled, "Electrodeposition of Chromium with Periodic Reverse and Pulsed Current," dated April 1976.

Summary Report was prepared by Robert S. Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 673 7257 and 674 7257 titled, "Squeeze Casting of Weapons Systems Components" were completed by Rodman Laboratory in September 1976 at a cost of $100,000 and $150,000 respectively.

BACKGROUND

The manufacture of weapon system components by conventional sand casting procedures is limited by certain physical constraints. Among these are porosity, undesirable microstructure, and low material yields of rough to finished part size. At the time of this proposal, squeeze casting was receiving considerable attention as a relatively new technology in the Western hemisphere. Its advantages are the elimination of porosity and undesirable microstructure, the economy of net or near net shape, and the capability for producing complex shapes.

As illustrated in Figure 1, squeeze casting consists of melting the work material; metering it through a tundish, (item numbered 1 in drawing) into a die cavity (2); moving the die in a cart (3), into the press; bringing the punch (4) down to displace the liquid or partially solid charge; applying pressure during solidification; and finally, opening the dies to eject the casting.

SUMMARY

The objective of this effort was to provide an improved production capability for the manufacture of weapon components which were made from sand castings. The items investigated were the receiver base and the barrel support of the M85 automatic gun. The following process variables were optimized during the experimental production of 300 squeeze castings: melt weight, pouring temperature, die temperature, time from start of pour to application of load, press speed, magnitude of the load and its duration, ejection cycle, and mold-separating agents.

Material requirements were substantially reduced. In the case of the barrel support, the raw casting weight was reduced from 80 pounds to about 14 pounds; and for the receiver base, from 47 pounds to 13 pounds. In addition, the surface finish obtained was far superior to that of a sand casting.

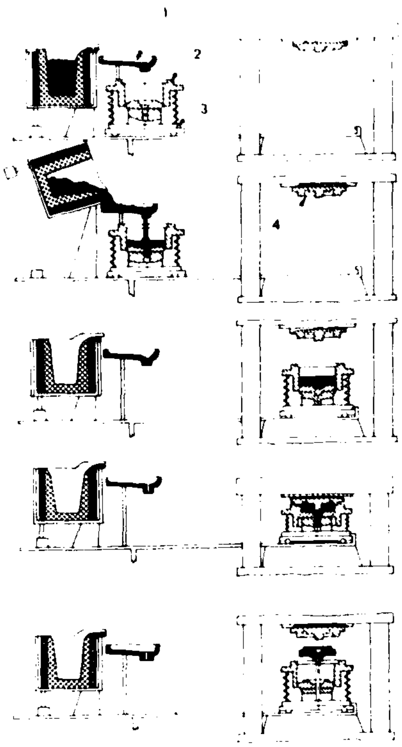


Figure 1 - Production Sequence for Squeeze Casting

BENEFITS

This project has established squeeze casting as a competitive fabrication technique for a variety of weapon components. The items whose process variables were optimized are no longer in production but other sand cast weapon components might benefit from the process with some additional effort.

IMPLEMENTATION

No implementation is anticipated with respect to the parts investigated. The technology gained from this effort is being used as one source of data in the ongoing project 578 6681 titled, "Process Parameters for Production Forming of Projectiles."

MORE INFORMATION

Additional information may be obtained by referring to the technical report R-CR-76-038 titled, "Squeeze Casting of Steel Weapon Components" dated September 1976, or by contacting Mr. R.B. Miclot at AV 793-6732 or Commercial (309) 794-6732.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 673 7268 titled, "Application and Establishment of Process Parameters for Depositing Electroless Aluminum Coatings" was completed by the US Army Armament Command in April 1975 at a cost of $64,000.

BACKGROUND

Aluminum is one of the metals that cannot be easily plated or deposited by conventional electroplating techniques. Therefore, aluminum has not been utilized as a metallic coating on conventional steel fire control items which require "blackening." On items where aluminum coatings are essential, special elaborate deposition methods and equipment are required. Steel parts are difficult to "blacken" to provide the surface durability, reliability, and corrosion resistance comparable to that obtained in "blackened" aluminum components. The advantages to be gained would be the utilization of the beneficial properties of aluminum; namely, good corrosion resistance and the receptiveness to finishes such as "blackening." The electroless process does not require the use of electricity, vacuum, or high temperature. This process also provides a means for deep cavity coating and uniform coverage of irregular steel surfaces.

SUMMARY

A number of proprietary and non-proprietary chemical and electrochemical processes are available for applying a black finish on steel. Such finishes find many applications for military equipment where reduced light reflectance is of importance as in optical instruments.

Limited information is available on the characteristics of black finishes for steel. This project was initiated to evaluate black finishes for steel that would be suitable for optical instrument applications and provide corrosion resistance, wear resistance, and light reflectance properties. Initially, attempts were made to apply electroless aluminum to steel and then blacken the aluminum. The results obtained from the plating of aluminum acetylacetonate onto steel indicated that corrosion resistance and color density of the coating were unacceptable for fire control instrument applications. Uniform electroless aluminum coatings could not be obtained.

Because of these unacceptable results, the effort was redirected to an evaluation of proprietary and non-proprietary chemical and electrochemical processes using materials such as caustic black oxide, black chromate for zinc or cadmium, black chromium plating bath, black nickel plating bath, and manganese phosphating solution.

It was determined that the best black finishes for optical applications was manganese phosphate and black chrome plate. Caustic blackened steel is relatively poor in corrosion resistance but provides substantial resistance to wear and abrasion. Only the manganese phosphate coating provided resistance to both wear and corrosion. The black chromated zinc or cadmium plated steel provided resistance to basic metal corrosion but white salts were evident after about 48 hours of salt spray exposure or 30 days of cyclic humidity exposure.

White light reflectance was low on all blackened surfaces. The lowest reflectance was observed on manganese phosphate and black chromium coated surfaces. Caustic blackening of sandblasted steel also results in a surface of extremely low reflectance. The blackened surfaces all reflected a higher percentage of infrared radiation than white light.

BENEFITS

The results of this project will provide the process by which optical black coatings can be applied to steel surfaces so as to provide non-reflective and corrosion resistant finishes suitable for fire control instrument application. It will also increase durability and reliability of the treated surfaces.

IMPLEMENTATION

The results will be implemented in current production of the M105 telescope and will also be implemented in future instruments. This will be accomplished by revising design practice procedures so that steel parts that must be blackened will receive the proper finish.

MORE INFORMATION

Additional information on this project can be obtained from Mr. N. Scott, ARRADCOM, AV 880-6430 or Commercial (201) 328-6430.

Summary Report was prepared by Robert S. Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 673 7300 titled, "Cold Rotary Forging of Small Caliber Gun Barrels" was completed by Rock Island Arsenal in June 1975 at a cost of $500,000.

BACKGROUND

The conventional method of manufacturing small caliber gun barrels involves rough, semi-finish, and finish metal removal processes to produce the outside contour, internal bore and rifling, and the chamber. In order to reduce cost and otherwise enhance the manufacturing process, interest had developed in the cold rotary forging process.

There is one manufacturer of cold rotary forging equipment with a recognized capability in the field. This is GFM of Austria. There are also several domestic manufacturers of cold forging machines, namely: Cincinnati, Fenn, and Fellows. However, the domestic equipment cannot simultaneously produce the inner and outer contours on the barrel, as can GFM equipment. For this reason, the GFM machine was selected for investigation.

SUMMARY

The objective of this program was to provide an improved method of manufacturing military gun barrels ranging in bore size from .22 to .50 caliber. During this project, suitable equipment was purchased and a pilot line for cold rotary forging of barrels was established.

Excellent bore qualities, reproducibility, reduced process time, and reduced tooling costs were demonstrated. By rifling, chambering, and simultaneous exterior contouring, it was shown that many conventional operations could be eliminated resulting in a gain in the production rate.

Table 1 depicts representative rotary forging cost savings which could be achieved. The dollar saving figures represent a 51% reduction in operating cost and a 90% reduction in tooling cost.

OPERATING COSTS
(Rifled & Chambered Barrel)

Conventional		Rotary Forge	
Drill barrel	.0758 Hr	Drill Blank	.0425 Hr
Rough Turn barrel	.1086 Hr	Turn Blank	.2000 Hr
Rough ream barrel	.0552 Hr		
Finish ream barrel	.0552 Hr		
Broach rifling	.0921 Hr		
	.3869	Forge rifling & chamber	.1167 Hr
Rough in chamber	.1123 Hr		
Semi-finish chamber	.1193 Hr		
Finish chamber	.1152 Hr		
	0.7337 Hr		0.3592 Hr

Operating Time Savings 0.3745 Hr Per Barrel

Operating Cost savings @ $22 per Hr $8.24 per Barrel

Operating Cost Savings	$8.24 per Barrel
Tooling Cost Savings	$5.38 per Barrel
Total Rotary Forge Savings	$13.62 per Barrel

Table 1 - Typical Cost Comparison of Conventional vs Rotary Forge Processing

BENEFITS

In addition to the reduction in cost, the following benefits would also accrue to this process: a) improved grain structure, increased toughness, better corrosion resistance, and finer surface finish; b) rotary forged barrels exceeded military accuracy requirements; c) bore variation was drastically reduced and straightness increased. Variations of less than .00015 inches were common.

IMPLEMENTATION

A technical report AOD-TR-75-001 has been issued. The rotary forge machine has been delivered to Dover, NJ. No further implementation is anticipated.

MORE INFORMATION

Additional information may be obtained by contacting Mr. John Jugenheimer at AV 793-4135 or Commercial (309) 794-4135.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 675 7409 titled, "Creep Forging of Aluminum Precision Components" was completed by Rock Island Arsenal in April 1978 at a cost of $150,000.

BACKGROUND

Because forging dies must have draft angles, large corner and fillet radii, and flash channels to facilitate material flow, conventionally forged aluminum precision components require extensive finish machining. The normal plasticity of aluminum alloys prevents the complete filling of complex die cavities when conventional forging techniques are used. Creep forging (low-rate deformation at constant pressure and in heated dies) improves the plasticity of materials, permits the complete filling of complex die cavities, and eliminates the requirements for draft angles, etc. Therefore, the cost of machining after creep forging can be reduced substantially.

SUMMARY

The objective of this project was to establish and document the manufacturing technology for creep forging aluminum weapon components.

The approach utilized the economics inherent in powder metallurgy processing to produce a preform, which was then creep forged to the finished part. The process variables investigated and optimized were powder particle size, preform density, sintering temperature, forging temperature, percent forging deformation, and tool design.

The effectiveness of the process was demonstrated by a prototype production of a cam component for the 105mm howitzer. Excellent cam forgings, free of any cracking and with complete die filling were made in a single forging operation. The forging had many net surfaces and a smooth finish; see Figure 1. Mechanical properties of the cam were practically the same in both longitudinal and transverse directions. In the longitudinal direction, the ultimate tensile strength, yield strength, and elongation were 72.4 ksi, 63.5 ksi, and 7.0% respectively. For purposes of comparison, wrought materials MIL-SPEC QQ-A-367H calls for longitudinal values of 75.0 ksi, 64.0 ksi, and 7%; and transverse values of 71.0 ksi, 61.0 ksi, and 3%.

A finalized process specification was recommended defining powder size, preform density, and sintering and forging conditions. Preliminary cost analysis projected a cost saving of 30% when the cam was made from a P/M forging as compared to a conventional forging.

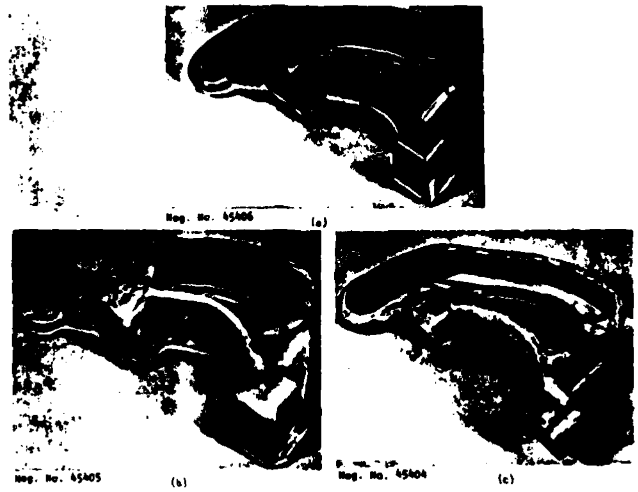


Figure 1 - Comparison of the Creep-Forged P/M Cam (a) with a Conventional Forging (b) and the Finish-Machined Part (c). (Note the near-net shape of the creep-forged P/M cam.)

BENEFITS

A process specification was developed for 7075 aluminum alloy P/M preforms. This specification was successfully demonstrated with the production of a complicated nonsymetrical component.

IMPLEMENTATION

The aggregate dollar savings are not sufficient to ammortize the equipment necessary to implement this technology. For this reason, there is no planned implementation.

MORE INFORMATION

Additional information may be obtained by contacting Mr. A. Crowson at AV 880-2596 or Commercial (201) 328-2596, or by referring to technical report no. TR-EN-78-04 titled, "Establishment of a Process for Creep Forging Aluminum Alloy Weapon Components" dated April 1978.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 674 7410 titled, "Fine-Blanking of Precision Small Caliber Weapon Parts" was completed by Rock Island Arsenal in November 1978 at a cost of $100,000.

BACKGROUND

Fine-blanking is a variation of the metal stamping process which produces close tolerance parts with edges and holes fully shaved through the entire part thickness. This eliminates further processing to provide smooth edges and uniform hole diameters where these are necessary. By way of contrast, conventional stamping produces a part having rough edges and non-uniform hole diameters, which in the case of small arms components, would require further processing.

In conventional metal stamping, a punch pushes the part out of the feed stock through a clearance hole in the die. This process produces a part with much of the edge surface broken away as shown in Figure 1.

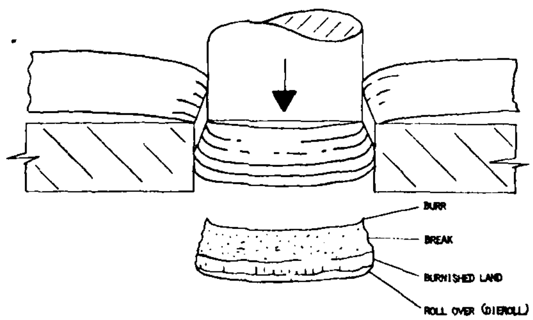


Figure 1 - Graphic Representation of Conventional Shearing

In the fine-blanking process, the feed stock is held between the top and bottom dies by a V-Groove. As the punch pushes the part out of the feed stock, a lower "punch" applies a counter pressure, which maintains flatness and prevents "breakaway" as the part is extruded through the die; see Figure 2.

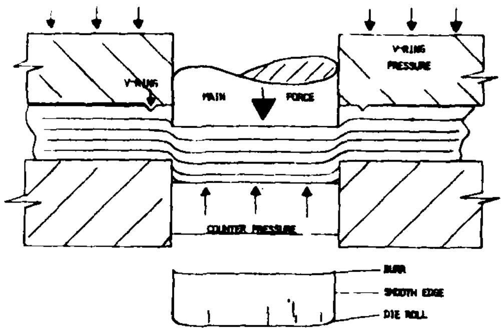


Figure 2 - Graphic Representation of
Fine-Blanking

SUMMARY

The objective of this project was to investigate the feasibility of fine-blanking small caliber weapon components to close tolerances and at a reduced cost when compared to conventional manufacturing processes. Of particular concern was the applicability of the fine-blanking process to the higher alloy materials required in small arms fabrication.

A large number of small arms components were studied and a group of suitable candidate parts identified. From this group, eight parts were selected which represented a variety of part size, shape, thickness, and material. Fine-blanking dies and a sample lot of blankings were produced for each of the eight parts. Five of the test parts were satisfactory; two parts could have been satisfactorily produced by changing part thickness or shape; and one part was unacceptable.

The estimated average savings per part produced was $5.19. The average die cost was $7,922.

Using an equipment cost of $490,000 for a 440 ton Feintool fine-blanking press, an average part savings of $5.19 and the 10% discount table, a five-year payback of equipment cost would require an annual production of 23,603 pieces. It would also require over 1,500 pieces of each different part produced to pay back the tooling cost of that item in one year.

BENEFITS

This project demonstrated that fine blanking is an effective and cost reducing process when properly utilized. Accuracy is very good, and the process can produce blanked forms which eliminate a large amount of finish machining.

IMPLEMENTATION

The test parts were used in production orders. The dies have been stored and production shop orders changed to reflect the availability of this tooling. If production quantities of applicable parts increase to economic levels, a fine-blanking press may be procured.

MORE INFORMATION

Additional information may be obtained by contacting Mr. John Jugenheimer at AV 793-4134 or Commerical (309) 794-4135 or by referring to the technical report number AOD-TR-78-001 dated November 1978 and titled, "Fine-Blanking Small Caliber Weapon Parts."

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 674 7411 titled, "Heat Setting Procedures for Helical Coiled Springs" was completed by Rodman Laboratory in December 1976 at a cost of $50,000.

BACKGROUND

The advantages of cold setting springs has been recognized for some time as a means of increasing the load carrying capacity of helical compression springs. The method consists of coiling the spring to a length somewhat greater than the final length desired and then compressing the spring beyond the elastic limit. The resulting permanent deflection produces a new, higher elastic limit due to strain hardening, thereby making the spring more resistant to deflection and to further setting in service.

Similar to the cold setting of springs, heat setting also induces favorable residual stresses within the spring material. However, heat setting is a more severe form of setting which produces a deeper and more permanent stress pattern and a correspondingly longer spring service life. The heat setting method differs from cold setting in that the springs are compressed on fixtures to a specified stress level and then subjected to a prescribed temperature for a specified period of time. A spring so treated will take some permanent set, and if the process parameters are correct, the completed spring will meet the desired specifications and will not take significant, additional set in subsequent service.

At the time of inception of this project, the M85 automatic gun used cold set springs. No other weapon system used either cold set or heat set springs.

SUMMARY

In this project, various heat setting procedures were investigated to determine optimum heat setting parameters for minimized operational spring set and load loss. Production springs were fabricated from music wire, stainless steel and chrome vanadium materials. One hundred and thirty springs of each material were given heat setting treatments under different conditions of temperature, time duration, and stress level. The effects of the various heat setting procedures on spring set and load loss were evaluated by laboratory endurance tests. Figure 1 outlines the parameters evaluated. In this figure, each set consisted of ten springs.

Springs compressed to a stress level of 100,000 psi

Set No.	Temperature(°F)	Time at temperature(min.)
1	200	30
2	200	60
3	300	30
4	300	60
5	400	30
6	400	60

Springs compressed to a stress level of 150,000 psi

Set No.	Temperature(°F)	Time at temperature(min.)
7	200	30
8	200	60
9	300	30
10	300	60
11	400	30
12	400	60
13	Controlled set - no heat setting applied	

Figure 1 - Spring Setting Parameters Evaluated

The heat setting procedure used on Set #1 proved to be the most effective to minimize operational load loss for the following materials and operating conditions:

For music wire (QQ-W-470) and chrome vanadium (QQ-W-412, Comp. 1)

Materials

Wire size approximately .043 inch
Stress range, 18,000 psi to 152,000 psi
Loading frequency, 1275 cycles per minute

For stainless steel (QQ-W-423, Comp. FS302) material

Wire size approximately .043 inch
Stress range, 41,000 psi to 139,000 psi
Loading frequency, 1000 cycles per minute

The untreated music wire springs (Set #13) suffered 4.45 times as much load loss and 2.9 times as much permanent deformation as the Set #1 springs during the endurance tests. These same relative figures for chrome vanadium were 4.66X and 2.71X; and for stainless steel, 3.09X and 1.83X.

BENEFITS

This project has particular application to small arms weapon systems since approximately 95 percent of all small arms springs are fabricated from the materials that were investigated in this study. Where applied, this process will enhance weapon reliability and will reduce spring replacement costs by five to ten percent.

IMPLEMENTATION

The results of this project were implemented in July 1975 at Rock Island Arsenal in the manufacture of the 5.56mm M16 rifle, the 20mm M39A3 automatic gun, and the 20mm M61 automatic gun.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Henry P. Swieskowski at AV 880-2666 or Commercial (201) 328-2666, or by referring to the final report no. R-TR-76-044 titled, "Heat Setting Procedures for Helical Coiled Springs" dated December 1976.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 674 7461 titled, "Application of Special-Tool and Process Machining to Sintered Powder Metal Weapon Components" was completed by the US Army Armament Material Command in February 1976 at a cost of $34,000.

BACKGROUND

The powder metallurgy (P/M) process is an economical method for the production of a variety of parts. As such, powder metallurgy parts and products have made inroads into traditional markets and production fields, including gears, hydraulic equipment, farm machinery, appliances, and even weapons.

While the goal of forged or sintered P/M parts is to eliminate sequential machining, in some cases machining is required. Consequently, the objective of this project was to establish machining processes and parameters for shaping, sizing, and finishing sintered powder metal weapon components.

SUMMARY

Machining tests were conducted using both low and high density P/M materials and wrought material. After the turning, drilling, reaming, boring, and tapping tests, drilled holes were axially plunge-ground with a solid carbide burr to check the effect on hole location, shape, and surface finish. The following conclusions were drawn from the test results: (1) a correlation between chip formation, cutting force characteristics, and surface roughness was demonstrated in three different materials, (2) the magnitude of the cutting forces in turning reflect the material properties to a great extent, (3) in the drilling process, drilling forces gave an excellent in- cation of the differences in material properties, (4) maximum spindle RP for drilling low density P/M material was obtained with a 0.5-inch diameter drill, (5) the tool wear in reaming is negligibly small, (6) reaming and boring processes cannot improve the hole geometry whose errors are displacement and parallelism, (7) in the boring process, the rigidity of the boring bar plays a significant role with respect to hole geometry improvement, (8) no burrs were observed in either low or high density P/M materials when tapping was conducted, (9) profiling and slotting by 2-flute and 4-flute end milling indicated no definite machinability characteristics, and (10) overall machinability of the investigated materials showed no significant trends since each material had its own advantages in specific machining processes.

BENEFITS

The processing parameters established through this project will reduce machining time, cost, and scrap in the manufacture of weapon components from powdered metal.

IMPLEMENTATION

The technical report for this project has been distributed to Army, Navy, and Air Force offices associated with the evaluation and application of new materials and manufacturing technologies.

MORE INFORMATION

Additional information concerning this project may be obtained from Mr. R.A. Kirschbaum, AV 793-5363 or Commercial (309) 794-5363, Engineering Directorate, Rock Island Arsenal, IL.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 675 7583 titled, "Application of Electro-Mechanical Machining (EMM) to Weapon Component Manufacturing" was completed by the US Army Armament Command in August 1976 at a cost of $89,000.

BACKGROUND

Many recoil mechanism parts require close tolerances and a very fine surface finish which is difficult to produce and requires expensive machining methods. Parts must be ground, honed, lapped, and hand polished to obtain the required surface finish and size tolerances. Electro-mechanical machining, developed in a laboratory environment by MMT projects 671 7035 and 672 7035, promised to reduce costs and provide an improved surface finish.

SUMMARY

The objective of this project was to design, build, and install the equipment and controls necessary to adapt EMM to existing lathes and drill presses. A master work plan was developed for the contractor and for Rock Island Arsenal. The contractor was to accomplish the following: 1) evaluation of insulation requirements, 2) development of non-corrosive electrolyte, 3) selection and testing of an effect biocide, 4) evaluation of polarization curves, 5) determination of optimum potentials with a new electrolyte, 6) development of a new ruggedized electrochemical circuit, 7) design and manufacture of a pumping system, and 8) evaluation of the mechanical properties of the alloys exposed to the non-corrosive electrolyte. Rock Island Arsenal responsibilities included the following: 1) overall plan for a test arrangement, 2) adaptation of a temporary electrolyte pumping system to a production lathe, 3) machining sample parts using both conventional methods and EMM, and 4) recording and evaluating all the machining parameters for both methods in order to compare the economics of EMM to conventional machining procedures.

Electro-mechanical machining laboratory techniques were adapted to a manufacturing environment at Rock Island Arsenal. A great deal of work was accomplished in the area of electrolyte development. Numerous corrosion inhibitors and biocides were tested and evaluated. The new electrolyte developed, while a major improvement over the old, uninhibited electrolyte, still proved too corrosive for extended production use as indicated in Figures 1 and 2.

Figure 1 - Corrosion Products and Electrolyte Deposits on Tool Slide

Figure 2 - Crystallized Electrolyte on Work Piece

BENEFITS

A nine percent cost reduction was identified in turning AISI 4140 steel with EMM as compared to conventional turning. However, as noted above, the electrolyte proved too corrosive for production use.

IMPLEMENTATION

Further development work, primarily in the area of a better non-corrosive electrolyte, will be needed before EMM is ready for production application.

MORE INFORMATION

A technical report titled, "Electromechanical Machining," report number AOD-TR-77-001, was issued at the conclusion of this project. It and additional information may be obtained by contacting Mr. J.D. Wilkins, Arsenal Operations Directorate, Rock Island Arsenal, AV 793-5897 or Commercial (309) 794-5897.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 677 7720 titled, "Establish Fabrication Procedures for Two and Three Wire Mesh Springs" was completed by the US Army Armament Research and Development Command in May 1979 at a cost of $50,000.

BACKGROUND

The stranded wire spring is the only helical spring configuration used in impact-loading applications. The use of stranded wire springs is recommended for applications in which the compression velocity is comparatively high; that is, in the order of 20 feet per second or higher. Velocities of this magnitude are common to the drive, extractor, ejector, and firing pin springs in automatic weapons. Stranded wire springs have the functional capacity to minimize the surge vibrations by the frictional interaction between the individual wires within the strand. This available dampening is effective in decreasing the dynamic coil displacement and in proportionately reducing the stress levels that result in longer spring life. Similar surge dampening and extended spring life can be attained with the use of mesh springs. However, mesh springs are relatively new and proper techniques have not been established for their fabrication.

SUMMARY

The objective of this project was to develop manufacturing techniques and procedures for the fabrication of two and three wire mesh springs on production coilers. The major problems in the present manufacturing of mesh springs are high production cost and excessive fabrication time.

A mesh spring assembly consists of two or three wires of equal diameters that are coiled together around the same axis into spring with equal coil diameters and equal number of coils. The appearance of a mesh spring differs from a stranded wire spring in that the individual wires are not stranded into a cable construction, but are separate and in contact with each other, see Figure 1.

Two designs of mesh spring assemblies were prepared for this project. They were the two spring mesh with a wire size of 0.045 inch and a three spring mesh with a wire size of 0.039 inch. Music wire QQ-W-470 and stainless steel wire QQ-W-423 were the two spring materials used.

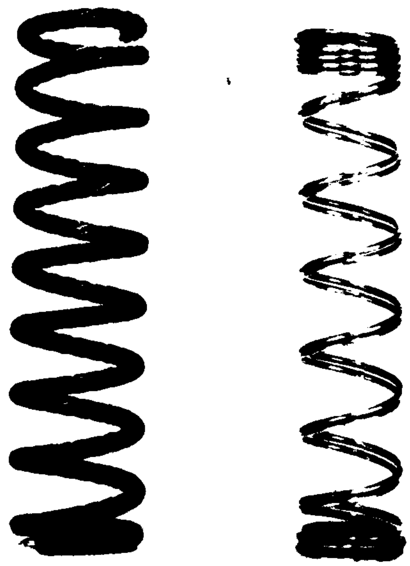


Figure 1 - Comparison of a Stranded Wire Spring
With Two Wire Mesh Spring

A segment type production coiler, rather than the arbor type, was used in this project because of the ease that is provided in the setting up and adjusting of components such as feed rollers, wire guides, and pitch cams.

Manufacturing procedures were established for the quantity production of two and three wire mesh springs on production coilers. Necessary tooling and modifications to facilitate the coiling of mesh springs were determined and adapted to the coiler. A two wire mesh spring and a three wire mesh spring were designed to equivalent conditions of load, stress, and outside coil diameter, and prototype lots of these designs were fabricated. It was determined that if the spring pitch equaled .50 inch or less, the mesh springs could be fabricated with good dimensional control. Mesh springs fabricated from stainless steel material was found to coil as easily as the music wire material. It was also determined that 1.5 to 2.0 coils should be closed on each spring to prevent separation. Endurance testing of the springs was not conducted due to the nonavailability of the Krouse spring tester.

BENEFITS

This project has established efficient methods for the quantity production of mesh springs and should lead to a broader use of this type spring. A significant cost savings can be realized due to improved manufacturing methods and increased operating life of these springs.

IMPLEMENTATION

The Technical Report No. ARSCD-TR-79010 titled, "Establish Fabrication Methods for Two and Three Wire Mesh Springs" was issued in August 1979. Endurance testing of the springs must be conducted prior to recommendation for implementation.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Henry Swieskowski, AV 880-5816 or Commercial (201) 328-5816.

Summary Report was prepared by Robert S. Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MUNITIONS

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 575 1250 titled, "Evaluation and Proveout of WP Munitions Leak Detection Prototype" was completed by the US Army Armament Research and Development Command in June 1978 at a cost of $325,000.

BACKGROUND

This program was initiated in support of interests to develop a highly automated dry fill line for white phosphorus (WP) munitions at Pine Bluff Arsenal. Currently WP munitions are tested for leaks prior to their shipment and/or storage by heating them to elevated temperatures in an oven for a specified time period and detecting leaks by observing the presence of smoke or residue spots. This type of testing was not considered optimum due to the limitations of the visual test and the mass of metal which must be heated. In addition, the current method is a risk to equipment and personnel. Therefore, the purpose of this project was to establish a cost effective and technically sound method for a leak detection system for WP filled munitions.

SUMMARY

The objective of this effort was to develop and test a prototype in-line leak detection system for WP filled munitions. The approach involved the determination of the fundamental characteristics of WP leakage through press fit munition closures. The system to be developed would have to be cost effective and energy conservative yet quantitative in its ability to detect the presence of WP leakage in a production line environment.

In order to establish the levels of sensitivity needed for proper leak testing and to determine causes of leakage found in the past, experimental studies were conducted simulating the press-fit joints used in assembling WP munitions. These assemblies were then subjected to varying levels of helium (HE) leak testing to determine the equivalent HE leak detection rate which would correspond to the initiation of WP leakage. The WP leakage comparison tests were conducted at the Chemical Systems Lab (CSL) using an experimental apparatus developed specifically for this program. The results of these tests showed that leakage of liquid WP occurred under applied pressures of approximately 25 psi. It also occurred through passages exhibiting helium leak rates of as small as 50×10^{-6} atm cc/sec under applied pressures of approximately 75 psi.

After surveying available leak testing techniques, a decision was made to utilize induction heating for thermal stressing of munitions coupled with a sensitive flame-emission detector. Preliminary induction heating systems were evaluated at Battelle, Columbus Laboratories, with a set of recommended operating parameters being established for use when stressing the munitions of interest. The table-top prototype unit fabricated and tested by Battelle is shown in Figure 1.

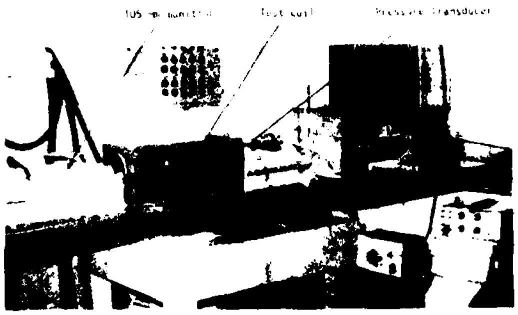


Figure 1 - Induction Heating Evaluation Unit

The unit consisted of induction coil, test chamber, miscellaneous instrumentation, and the coil power unit (not shown).

After establishing the induction heating system, bench type equipment was fabricated to conduct leak tests using a flame photometric detector. The laboratory set-up is shown in Figure 2.

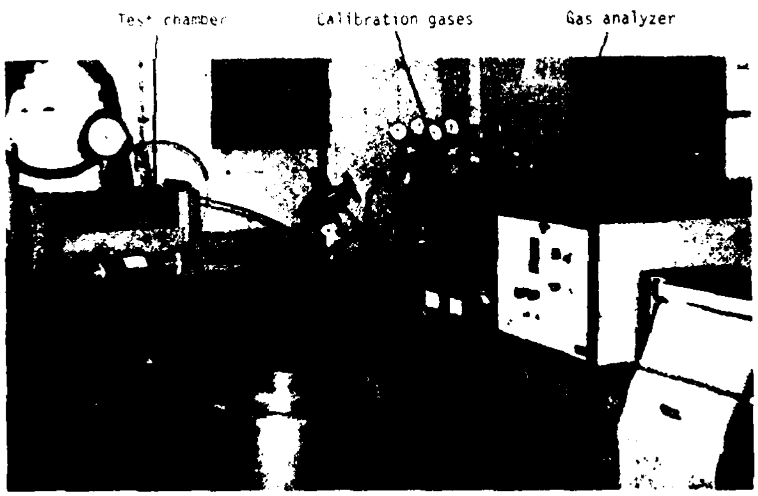


Figure 2 - Flame Photometric Gas Analyzer for Detecting Phosphorus

The procedure was to heat the munition in the induction coil and allow it to stand for a short period before placing in the test chamber. The chamber was then flushed for residual WP fumes and a sample of the gases leaking around the shell were drawn off and tested in the detector for phosphorus content. Results of the laboratory studies indicated that induction heating was a viable means for thermally stressing munitions for leak detection. Similarly, the use of a flame-emission detection apparatus was effective as a sensitive detector of WP fumes.

A single-round test station was then assembled and installed for field assessment of the thermal/flame emission detection concept at Pine Bluff Arsenal (PBA). Instrumented WP rounds were run through the system to verify the recommended set of operating parameters established at Battelle. Following the verification testing, 712 WP filled munitions, M60 105mm, coming off the dry fill line at PBA were leak tested. Only one of the M60 cartridges was found to be a definite leaker. During comparison batch oven testing, no leakers were found.

To determine how effective this sytem would be on munitions coming off the wet-fill line at PBA, 102 M416, 105mm cartridges were tested. While seven were found to be contaminated externally, there were no leakers tested. In correlation tests with existing procedures, there were also no leakers found in the batch oven testing.

Performance results to date indicate that this method of thermal stressing and WP detection can serve as a well controlled means to check WP filled munitions during their inspection for leaks. However, only limited data was gathered to determine the reliability of the system to actually identify detrimental leakage levels. Therefore, it was recommended that the prototype system be used at PBA in a continuing series of experiments to establish the correlation of leakage rates predicted by the induction heating scheme with those found using normal batch heating techniques.

BENEFITS

This effort resulted in a leak detection method which will shorten the test time required, reduce energy costs, eliminate visual observation, and allow a safer operation.

IMPLEMENTATION

The prototype in-line leak detection system is planned to replace the present oven system at PBA. This will be accomplished by a planned follow-on MMT project to provide an automated leak detection system. Future WP dry lines will have a leak detection system incorporated in-line.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. D. Patton, AV 584-3895 or Commercial (301) 671-3895.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 573 1264, 574 1264, 575 1264, 576 1264, and 57T 1264 titled, "Advanced Technology for Suppressive Shielding of Hazardous Production and Supply Operations" were completed by the US Army Armament Research and Development Command in June 1979 at cost of $413,000, $1,500,000, $3,300,000, $1,450,000, and $100,000 respectively.

BACKGROUND

A suppressive shield is a vented steel structure designed to resist the effects of accidental explosions. In modernizing the ammunition production base, the Army determined a need for new designs of protective shields for application in hazardous manufacturing, transportation, storage, demilitarization, and disposal situations.

SUMMARY

The purpose of these projects was to support the Army's Modernization Plan. The overall objective of this effort was to design, fabricate, and test prototype shields for specific hazardous operations for the protection of personnel and equipment during operations involving high explosives or pyrotechnics. As a means of facilitating the testing and application of suppressive shields to the Production Base Modernization and Expansion Program, several groups of shields were defined, see Figure 1. Groups of shields ranged from those designed to withstand light blast pressures (less than 50 psi) to those designed to withstand ultra high blast pressure (from 500 to 2000 psi).

Project accomplishments for this effort were too numerous to include in this report. Three examples of tasks undertaken by these projects were selected and are described here to demonstrate typical accomplishments. The first task, "Analysis and Evaluation of Suppressive Shields," was accomplished through comparisons between analysis and experiments of three complicated phenomena. These phenomena include:

a) overpressures inside and outside a vented enclosure produced by the detonation of high explosive charges or by burning of propellants.

b) transient loading on the structural components of the shield produced by the overpressures, fragments, and thermal environment.

c) elastic-plastic response of the shield to the transient loading.

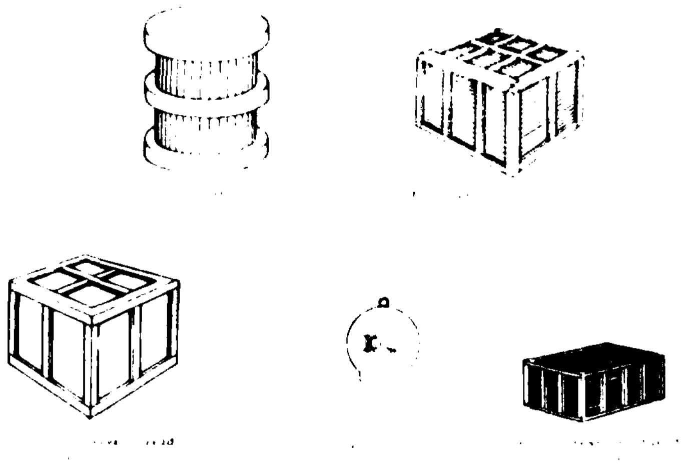


Figure 1 - General Configuration of Suppressive Shield Groups

The second task, "Near Field Blast Effects from Bare Charges," tested simple ionization probes for the [illegible] arrival measurements at small scaled distances, ground-plane blast-pressure measurements which were then correlated with published reflection coefficients and an optical distortion method for observing [illegible].

The third task, "Blast Pressures Inside and Outside Suppressive Structures" tested methods for estimating shock pressures and vented gas pressures from within structures and for estimating attenuated blast wave properties outside.

BENEFITS

The results of this effort developed new designs for safety shields which will be applicable to new constructions and modernization of old facilities to enhance safety in munitions manufacturing facilities.

IMPLEMENTATION

Test results are being incorporated into the design handbook, HNDM-1110-1-2, 18 Nov 77, titled, "Suppressive Shields, Structural Design and Analysis Handbook," published by the US Army Corps of Engineers.

MORE INFORMATION

Additional information and technical reports for this project are available from Mr. J.R. Marsicovete, ARRADCOM, AV 880-3906 or Commercial (201) 328-3906.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 576 1313 titled, "Assessment of the Hazards Involved in the Production of Pyrotechnic Compositions" was completed by the US Army Armament Research and Development Command in April 1978 at a cost of $550,000.

BACKGROUND

Prior work had been done in the field of hazard analysis of pyrotechnic compositions under project 57X 4099 by Chemical Systems Laboratory and was concerned primarily with classification testing of pyrotechnic compositions and end items. Upon completion of the project, one major area of pyrotechnic hazard analysis was found to be insufficiently described. There was a lack of information upon which to base hazards evaluations of full scale blending and materials handling processes. By evaluating these manufacturing processes, it may be found that safety standards regulating the manufacture of pyrotechnics do not accurately reflect actual manufacturing hazards. Currently, blending operations of smoke mixes are classified in explosive Class-7 which limits batch sizes to 125 pounds. After evaluating the manufacturing processes, a more accurate hazard classification can be made based on test results. For some processes involving certain pyrotechnics, a hazard classification change may be warranted. If so, a significant increase in batch size could be realized yielding the potential for an impressive cost reduction due to increased productivity.

SUMMARY

The primary objectives of this effort were to investigate the potential hazards associated with manufacturing pyrotechnics compositions and provide technical information which may be used to improve safety regulations gov- ing the manufacture of pyrotechnics. This was accomplished by determini the classification during pyrotechnics blending operations and then determining the true and accurate hazard classification of these operations. Additional work studied the effects of confinement of pyrotechnics, the detection and control of fires and explosives, and the classification tests of new compositions and end items.

The project was divided into nine interrelated tasks. These nine tasks are described briefly along with the results.

<u>Electrostatic generation by pyrotechnic compositions in pneumatic conveying systems</u>. The objective was to determine the electrostatic behavior of pyrotechnic materials and investigate methods for measurement of the electrostatic charge accumulation in a pneumatic transfer system. Bulk colored

smoke components in sliding contact with various surfaces were measured for charge generation with a Faraday pail. It was found that ionic substances such as sodium bicarbonate and potassium chlorate produced charges lower in magnitude than dyes or sulfur. To evaluate the behavior of materials under actual pneumatic conveying processes, a tube hopper apparatus was utilized. Charges on the order of 10^{-7} coulomb seconds per foot was observed.

Pyrotechnic reaction measurements by Bomb calorimetry. The objective was to measure the energy output and reaction rate of pyrotechnic compositions using a large-scale bomb calorimeter. A series of tests were performed using green, red, yellow, and violet smoke compositions. Results indicated that 1) the violet smoke mix is most energetic followed by red, green, and yellow, 2) energy output increases with decreasing sample density, and 3) the energy output increases significantly with increased ambient pressure.

Friction stimuli in blending operations. The objective was to determine the occurrence of ignition due to friction during process blending and mixing. Tests were performed on various pyromixes to determine if ignition could be induced by introduction of foreign objects and metal to metal contacts. Results indicated that the frictional energy required to ignite pyrotechnic compositions was greater than those generated by the experiments. Therefore, the initiation of pyrotechnics by friction during blending processes was judged less hazardous than previously postulated based on reported incidents.

Evaluation of violet smoke initiation in Jet Airmix Blender. The purpose of this task was to determine the hazard associated with blending smoke mixes in the Jet Airmix Blender. Results of tests indicated that there was no mass detonation tendencies of violet smoke mix (1000 pounds) when subjected to thermal initiation during [illegible] pneumatic dispersion in a Jet Airmix simulater. This eased the restrictions placed on the maximum batch size permitted.

Pyrotechnic Blending in a Double Cone Mixer. The objective was to determine triboelectrication effects and thermal effects, and to evaluate the requirements for minimizing the hazards associated with full-scale blending. Experiments were performed by thermally igniting the pyromix during blending. Results indicated that the electrostatic energy generated was one to two orders of magnitude less than the minimum energy required for initiation. Only small temperature changes were observed which were of minimal concern. Two experiments were performed in identical standard double cone blenders. One of the blenders had a rupture disc and a water deluge system activated by a remote sensing element added. Each experiment consisted of thermally igniting 500 lbs of violet smoke mix. The first experiment resulted in total destruction of the blender. In the second experiment, the blender remained intact and serviceable with the rupture disc relieving the developed gas pressure. The suppression system minimized the hazards of the post ignition events and precluded a dust explosion. The addition of a rupture disc prevented rupture of the blending vessel and reduced the hazards.

Mass effects of pyrotechnics during blending operations. Tests were performed to determine if there was evidence of a critical mass above which pyrotechnics, when thermally or explosively ignited, would produce a high order deflagration or detonation. No test performed in vented and unvented enclosures using quantities up to 600 lbs of mix produced more than a vigorous burning reaction. There was no evidence of deflagration or detonation.

Effects of Confinement on pyrotechnic reactions. The effect of confinement on a deflagrating composition was evaluated in a closed structure similar in size and configuration to cubicles typically found in pyrotechnic facilities. The test results showed that reaction rate increases significantly as the charge/volume ratio increases within an enclosure and that flame propagation barriers must be sufficiently constructed to eliminate convection.

Detection and control of dust fires and explosion. The characteristics of sulfur dust fires and a method for control based on ultraviolet detection and high pressure suppression were investigated. Sulfur/air dispersions were found to be subject to low-order detonations, accompanied by relatively slow-moving flame fronts. A high pressure quench system, with a burst diaphragm triggered from an ultraviolet sensor, was found to control these reactions satisfactorily. Water was found to be less efficient as a suppressant than halogenated hydrocarbons.

Explosive classification testing. Bulk material and end items hazard classification tests were performed on four experimental M18 colored smoke formulations made from coarse ingredients. Compared to standard mixes, the new red, yellow, green, and violet smoke compositions yielded essentially identical test results for thermal stability, card gap, and burning tests but indicated greatly enhanced sensitivity toward impact. Detonation and external heat tests on packaged grenade end items made from the experimental materials have no evidence of intergrenade propagation, explosion, or fragment dispersal.

BENEFITS

Benefits will accrue from the reduction of hazards classification for blending operations and bulk composition. This will result in increased batch sizes from 125 pounds up to 500-800 pounds, reduction in cost of end items, reduction in quantity-distance relationships, and reduction in facility construction and shipping costs.

IMPLEMENTATION

Final reports were published and distributed to organizations requiring this type of information. Information on hazard classification testing was provided to the Chemical Systems Laboratory Safety Office for dissemination and forwarding through safety approval channels.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. Stega, AV 584-2301 or Commercial (301) 671-2301.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 575 1316 titled, "Advanced Technology for Processing Smoke Grenades" was completed by the US Army Armament Research and Development Command in November 1978 at a cost of $500,000.

BACKGROUND

Historically, problems have been encountered while filling and pressing hexachloroethane (HC) and colored smoke grenades at Government and contractor's plants. Problems were related to: (1) accurately measuring the fill material, (2) excessive dusting (airborne) while filling and pressing the material, (3) the need to ream the fill material to a specific height, and (4) lack of pressing data on ram speeds and dwell time. Several years ago, the Government contracted to have automatic, high speed fill and press machines developed which would overcome some of these problems. The contractor failed, however, to develop an acceptable machine. This meant that Pine Bluff Arsenal (PBA) had to continue to fill grenades by hand. Prior to contracting for other machines, it was determined that studies had to be conducted in order to obtain basic data required to select the best processes and equipment to economically and safely fill and press grenades.

SUMMARY

The purpose of this project was to provide the Government with essential technology and proven procedures to economically, safely, and reliably fill and press high quality grenades within OSHA standards. Both the Chemical Systems Laboratory (CSL) and Pine Bluff Arsenal (PBA) performed a broad-based study of methods of filling and pressing grenades.

The tasks performed involved studying the (1) conveying of filled grenade cans, (2) filling of grenade cans, (3) loading variables, (4) effects of expansion, and (5) various mix forms.

The conveying study determined to what depth a grenade could be filled with loose mix so that it could be conveyed at a reasonable speed without spillage. It was found that the maximum allowable conveyor speed varied with the type of mix. If the mix was a standard dry blended colored smoke mix, with at least 1/4-inch free space left, the maximum allowable speed was 33 feet per minute. For the acetone granulated mix, the grenade could

travel at 45 feet per minute. For coarse mix, the grenade could travel at 54 feet per minute without spillage. HC mix could not be conveyed faster than 18 feet per minute without spillage.

Filling studies involved the loading of cans with loose powder to determine problems associated with the interface between the cans and the filling device and to determine the practicality of filling with the premeasured or preweighted increments of loose mix. A clean method for filling the grenade can was demonstrated by use of a filling device that seals the grenade can while the mix is being loaded into the can. When the grenade was filled with two or three preweighted increments, consistent and acceptable fill heights were achieved.

The loading variables were studied to determine the pressing force relationship, the press ram rate/dwell relationship, and the severity and control of dust generated during the pressing operation.

The equipment used for this study is shown as the complete station in Figure 1.

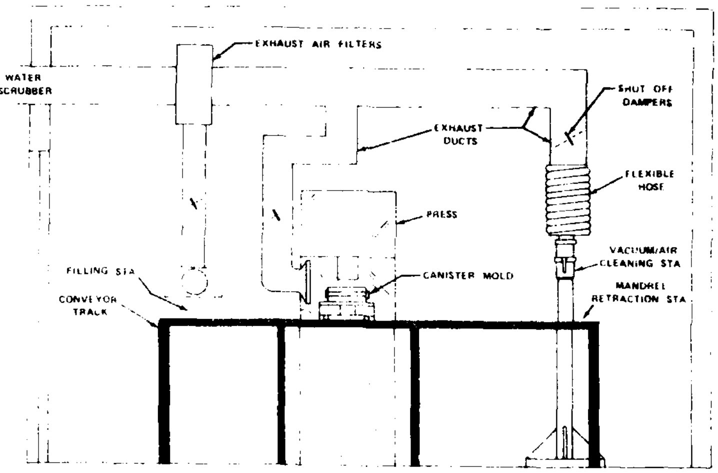


Figure 1 - Grenade Filling, Pressing, and Cleaning Stations

The ten ton press is indicated along with the mold below mounted on rollers. A conveyor track is shown for moving the mold from the mix loading station to the press and on to the mandrel retraction and grenade cleaning station. An exhaust air hood is shown at each station with a capacity of 800 feet per minute. A vacuum suction device is provided to clean smoke mix surfaces after mix compaction, mandrel retraction, and prior to can removal from the mold.

Test results showed that press forces as low as 3500 pounds produced grenades that functioned even after rough handling. This was true for the grenades made with acetone granulated or coarse mixes. X-rays taken of these grenades showed that the pressed material within the can shifted when rough handled so that it moved toward the top of the can. This was objectionable, since movement of the mix could result in a grenade malfunction. It was found, however, that when the material was pressed at 5000 pounds or higher, this phenomena was not a problem.

Varying the ram rate was shown to have an insignificant effect on grenade quality and performance for grenades consolidated at pressures between 3500 and 800 pounds. Varying the dwell time for the press ram at full pressure produced no significant effect on grenade quality or burning time.

In the can expansion effort, it was determined that a grenade can would expand to the size of the confining mold during pressing but it would not continue to expand after the mold was released. A mold dwell time of one second was found sufficient to insure complete release of the ram pressing force before the mold is released.

The mix forms investigated were the standard fine, coarse, and acetone granulated mixes. The fine mix was found difficult to deaerate, and during pressing, a fine coating of mix remained in equipment which could not be removed by exhaust or air jet. Spills were impossible to clean up completely by exhaust and/or air jet due to the obstinate dust coating left on any surface contacted by the mix. The coarse mixes were found to be very free-flowing and suitable for both vibratory feeding and for weight or volumetric filling methods. Cleaning of the powdered surfaces was easily accomplished. The advantages associated with acetone granulated mixes are: ease of handling, lowest percentage of fine dust, suitability to vibratory feeding, adaptability to weight or volumetric filling, and good dust control.

BENEFITS

This project provided the technology for improved manufacturing procedures for white and colored smoke grenades. Direct benefits include (1) cost reduction through elimination of operations and operators, (2) safety and hygiene improvements through improved procedures, elimination of operations, isolation of operators and automation of function, and (3) reduction of pollution abatement costs through control of materials entering waste treatment system.

IMPLEMENTATION

This technology will be implemented in project 581 0280 which will provide Pine Bluff Arsenal with an automated M18 colored smoke grenade production facility that is efficient, safe, makes quality grenades, and complies with OSHA requirements.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. C. Ferrett, AV 584-3007 or Commercial (301) 671-3007.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 576 1319 titled, "Process Design for Impregnating Wicks with WP" was completed by the US Army Armament Research and Development Command in November 1977 at a cost of $300,000.

BACKGROUND

During a review of the present smoke obscuration capability of the Army, it was noted (based on actual military experience) that significant gaps and functional deficiencies existed in present munition inventories and supporting technology. White phosphorus (WP), when disseminated explosively, shatters into small particles which burn rapidly causing pillaring and loss of about two-thirds of the ground screening smoke. Preliminary investigations indicated that a munition capable of disseminating a long burning source of screening smoke could be expeditiously developed with the current state-of-the-art. The use of a wick type material to absorb the WP has been studied. When ejected from the munition, these wicks burn in a defined area and produce an effective smoke screen of five minutes or more duration. This study was initiated to develop the technology to completely impregnate the wick material with WP using the most economical mass production technique.

SUMMARY

The objective of this program was to provide mass production technology for filling improved WP munitions incorporating wick material. This effort was applicable to WP munitions presently being developed (2.75" Rocket and 155mm Projectile) as well as future munition developments employing such absorbent materials. Studies included determining the characteristics of wick material with respect to filling and factors affecting filling of wicks and wick type munitions such as temperature, vacuum, time, and filling techniques. The production feasibility of techniques and methods considered for wick and wick type munitions filling was also determined.

The volumetric-filling concept, proven under MMT project 575 1274, "WP Dry-Fill Line," was selected for use and the filling system was designed so that variations in WP temperature, canister pressure, and control system effects could be studied.

The canister (2.75" Rocket Warhead, M259) studied in this effort was fabricated from extruded aluminum tubing with machined aluminum end plates welded to the tubing. The canister contained ten wicks made from formed perforated steel plate with a fiber glass filler as shown in Figure 1.

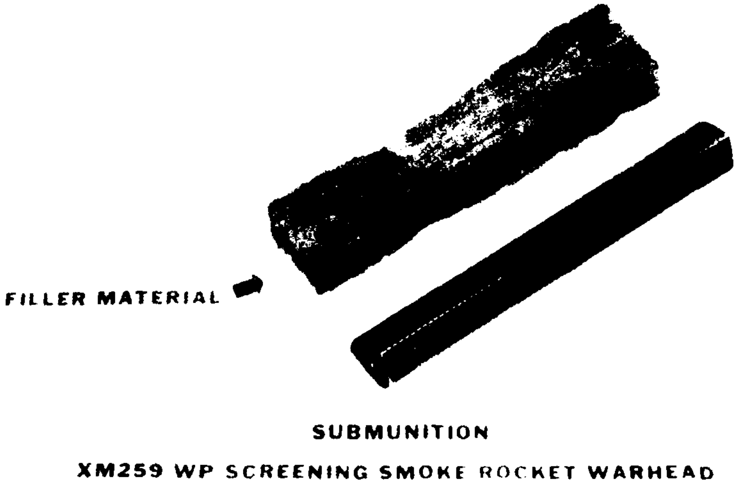


Figure 1 - Perforated Metal Wick

Facsimile canisters were designed and constructed from clear acrylic tubing for the purpose of observing the filling of the wicks and canisters. The canisters shown in Figure 2 were designed for easy filling, disassembly, and cleaning for reuse.

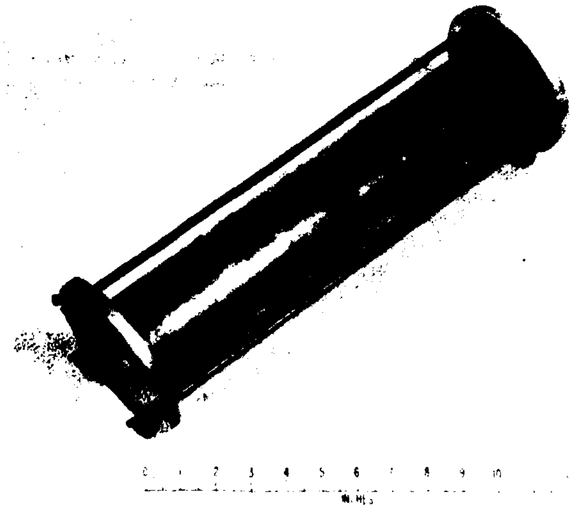


Figure 2 - Assembled 2.75 Inch Facsimile Canister

A test program was then conducted to establish a set of parameters for WP filling of the canister of the 2.75" M259 improved smoke warhead. The parameters determined were the effect of preheating the canister, WP temperature, vacuum level, and burster tube size. The following results were obtained: (1) The 2.75" canister does not require preheating before filling, (2) a fill time of five-six seconds (WP flow time) can be achieved without vacuum with 160°F WP. Approximately two seconds can be gained by using a 20-inch hg vacuum; however, when the time required to pull the vacuum on the canister is considered, there is little difference in total cycle time, (3) WP temperature within the range considered (140°-180°F) has little effect on fill time, and (4) a canister configuration with a longer and larger diameter burster tube was tested as a result of plans by the R&D program to incorporate a large burster. The configurations tested resulted in approximately one second increase in fill time.

Although the actual filling time was minimal, under vacuum, the time required to evacuate the canister and the added complexity of the overall filling system increased the filling time over that time required for no vacuum, no preheat, and 160°F WP. Therefore, the latter conditions were concluded as optimal.

Based on the optimum conditions determined, (160°F WP; no vacuum, no preheat) a total of 52 test canisters were successfully filled. During the standard oven leak test of 160°F for eight hours, eight test samples leaked. The process data obtained served as a basis for a follow-on pilot line fabrication and prove-out of production type filling, closing, and testing the total round.

BENEFITS

This project provided the baseline data for equipment design for follow-on projects leading to an initial production facility for the M259/XM264 2.75 inch rocket warheads. The data generated will also be applicable to other munitions using similar type wicks.

IMPLEMENTATION

The data was utilized for equipment design/procurement by MMT projects 576 1336 and 577 1320.

MORE INFORMATION

Additional information is available from Mr. M Erickson, ARRADCOM, Chemical Systems Laboratory, AV 584-2390 or Commercial (301) 671-2390.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 57T 1337 and 577 1337 titled, "Engineering Studies for Adoptive Transfer of United Kingdom Technology: RP/Butyl Grenades" were completed by the US Army Armament Research and Development Command in October 1979 at costs of $250,000 and $354,000 respectively.

BACKGROUND

As a result of lessons learned from the 1973 mid-East conflict and subsequent findings of a special task force in tactical use of smokes, TRADOC established firm high priority requirements for smoke items. The DA approved material need for the M60A1 tank includes the requirement for a protective smoke system. The L8A1 Red Phosphorous (RP) smoke screening grenade developed by the United Kingdom was found to satisfy the requirement for a nearly instantaneous smoke curtain for the M60A1 tank. Therefore, in August 1975, a decision was made by the US Army Materiel Development and Readiness Command (DARCOM) to establish a United States production capability for the United Kingdom L8A1 RP smoke screening grenade. An agreement was signed in December 1976 between the US and the UK for sale of the technical data package (TDP) to the US for the grenade including the production technology.

The RP grenade as developed and standardized by the UK, is shown in Figure 1.

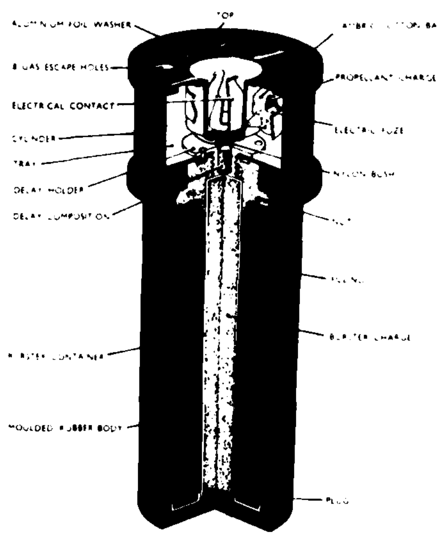


Figure 1 - Grenade, Smoke, Screening, L8A1

SUMMARY

Since the Army had little experience in producing RP filled munitions, this effort emphasized investigation of the UK chemical and mechanical process and adopting them into a US description of manufacture for the design and construction of the initial production facility (IPF). The major objectives being to establish a process baseline for filling and assembling the L8A1 grenade and developing in-house expertise on process techniques of RP for use in munitions.

The project effort involved three major areas of activity at Edgewood Arsenal, Aberdeen Proving Ground, MD. The first phase was the procurement and fabrication of equipment to reproduce the UK operation. After assembling the equipment into a pilot plant, process studies were conducted on each operation to establish the optimum conditions. A flow sheet for the pellet preparation is shown in Figure 2.

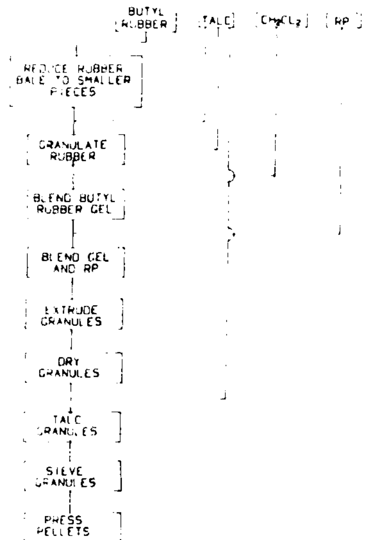


Figure 2 - Operation Flow Sheet for Pellet Preparation

It consisted of preparation of the butyl rubber/dichloromethane binder system, blending the binder with red phosphorus, drying this mix, and extruding the pellets. The pellets were then pressed into a disk configuration. Filling consisted of loading the rubber grenade body with smoke disks and pressing them at 250kg. This was followed by loading the pyrotechnic charges and completion of assembly.

At the conclusion of Phase I efforts, RP pellets were successfully produced which met all specifications if the optimized parameters cited for each operation were followed.

The second phase involved establishing US equipment, parts, and materials for the grenade. This effort was concurrent with phase one. As a result of this work, a list and description of equipment recommended for the initial production facility was prepared.

In the third phase of the project, grenades were produced to verify the process and procedures developed in phase one by subjecting them to a test program. The test program consisted of a hazards analysis and field testing. The hazards analysis would provide results of classification testing and evaluate the worst case hazards during the blending/mixing operations. Results indicated that the RP/butyl mix did not exhibit characteristics of detonation in any of the standard classification tests nor did it show any hazardous characteristics during blending.

Field tests were conducted to evaluate the effects of significant variations in the pellet processing. This was accomplished by fabricating a series of grenades with induced defects or variations. Results showed that none of the induced defects or variables made any significant difference in the grenade performance as compared to the standard UK L8A1 grenade. This eliminated the need for x-ray examination of each pellet in production to assure its integrity.

A process baseline was prepared consisting of the technical data package developed for the pilot line. It also consisted of a description of the pilot equipment used including operating procedures and drying curves. In addition, it included recommendations for equipment and environmental, safety, and quality assurance guidelines.

BENEFITS

It was demonstrated that US equipment was able to be adapted to produce the UK L8A1 RP grenade. In-house expertise was also developed by conducting process studies.

IMPLEMENTATION

The technical data package developed in the project was used to complete the design of the IPF for L8A1 RP grenades. This package will be used for the procurement and installation of the equipment under facility project 580 0037.

MORE INFORMATION

Additional information is available from Mr. F. Stewart, US Army Armament Research and Development Command, Chemical Systems Laboratory, AV 584-2661 or Commercial (301) 671-2661.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 571 4000 and 573 4000 titled, "Automated Detonator Production Equipment" was completed by the US Army Armament Research and Development Command in May 1975 at a cost of $750,000.

BACKGROUND

With the advent of Improved Conventional Munitions, the requirement for non-electric detonators increased to 100M/month at mobilization and 100M/year in peacetime. Current detonator equipment is World War II vintage which requires large facility space and is highly labor intensive. These projects were to conceive, design and fabricate automated equipment for the manufacture and inspection of non-electric detonators. Figure 1 shows the M55 detonator. The dimensions of the cup and the requirement for three different primer explosives evidences the high speed production difficulties.

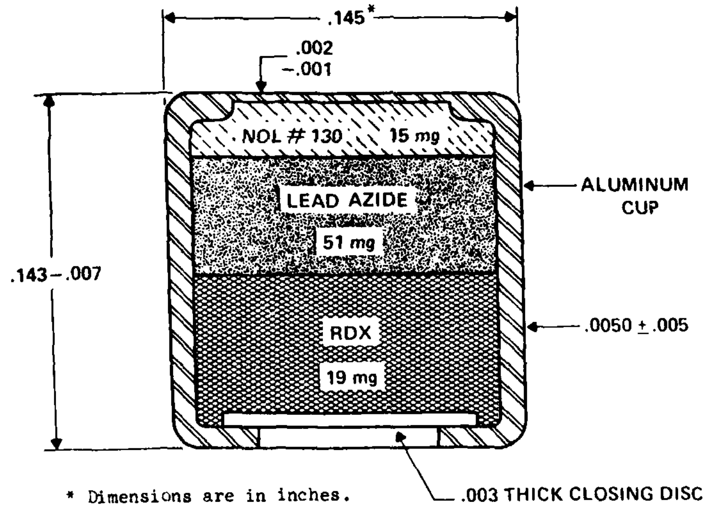


Figure 1 - M55 STAB Detonator

SUMMARY

The objective of these projects was threefold:

a. Study the manufacturing technology available or adaptable to the production of detonators.

b. Conceive and evaluate new techniques for detonator production.

c. Fabricate and evaluate prototype stations for loading, sealing, inspecting, and packing detonators.

The first step was to contract with Gulf & Western Corp. for a survey of the techniques and equipment available for automatic production, inspection, and packing of non-electric detonators at a design rate of 1200 parts per minute. This survey consisted of a literature search of high rate equipment and visits to Army detonator production facilities. The survey concluded that state-of-the-art equipment was available to develop the detonator production system. However, a requirement for development work was anticipated for the loading and compaction of explosives. This work was due to the sensitivity, explosive power, and handling characteristics of the explosive powders.

During the second step, MRC, Bulova, and FMC were each awarded contracts to devise concepts for loading detonators at 1200 per minute rate. Each contractor built a bench model for loading detonators. Each concept utilized a rotary press and on-the-fly feeding of explosives. The concepts differed in the operational mechanics; that is, material handling, method of metering the explosives, and compaction techniques.

The next step involved conception and proof modeling of crimping and sealing equipment. MRC and Sonobond were awarded contacts to independently develop the equipment. MRC's concept involved three independent rotary turrets for inserting closing disk, crimping, and lacquering. Transfer between the turrets was accomplished via a starwheel. Sonobond Corp was contracted to demonstrate the feasibility of ultrasonic ring welding to achieve a hermetic seal. To achieve this goal, development of ultrasonic welding equipment was initiated. However, this equipment was never proved out because of financial circumstances.

FMC's initial contract plus a later contract involved conception and proof modeling of stations to crimp, lacquer, and pack the detonator. FMC recommended the crimp be accomplished by two rotary turrets. One would perform a 45° crimp and the other would complete the crimping action. Sealant application could be performed with a special polypropylene dabbing tip. This tip, commercially available, is designed to meter the same amount of liquid each time the plunger is depressed. Inspection for sealant could be done by stationary optical scanners.

FMC surveyed current high speed packing equipment and found it infeasible for detonator packout. FMC developed bench models to demonstrate their packing concept. The detonators would be transferred individually from the previous operation to the packout line in a nylon disk carrier. The carriers would be 0.437 inches in diameter, which is the size of the nest in the detonator inner pack. Therefore, after five rows of ten carriers are lined up, they could be transferred to the detonator inner pack box.

BENEFITS

These projects conceptualized and fabricated bench models of high speed equipment and techniques which could apply to detonator production. The proof models demonstrated that explosive powders could be metered, dispensed, and consolidated while the detonator cups are moving continuously. These proof models also aided in the advancement of the state-of-the-art in detonator production.

IMPLEMENTATION

The results of these projects were to be implemented through the design and construction of an automated pilot line for high speed production of detonators. However, prior to pilot line construction, a new concept for increasing the output of the current detonator loading machine was investigated. This concept involved adapting an existing Iowa detonator loader to accept multiple tooled work stations. This increased the output of this machine by more than threefold. With the current mobilization rates, these multi-tooled Iowa loaders were more economical and required less development time. Therefore, the high speed loading concept was terminated. However, much of the technical data developed in these projects can be used in the development of ancillary equipment to support the multi-tooled loader.

MORE INFORMATION

Additional information may be obtained from Mr. Paul Monteleone, ARRADCOM, AV 880-5389 or Commercial (201) 328-5389.

Summary Report was prepared by Mickey Carter, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 575 4000 and 576 4000 titled, "Automated Detonator Production Equipment" was completed by the US Army Armament Research and Development Command in May 1975 at a cost of $1,100,000.

BACKGROUND

With the advent of Improved Conventional Munitions, the requirement for non-electric detonators increased to 100M/month at mobilization and 100M/year in peacetime. Current detonator equipment is World War II vintage which requires large facility space and is highly labor intensive. These projects were to conceive, design, and fabricate automated equipment for the manufacture and inspection of non-electric detonators. This effort was previously funded in FY71 and FY72. During these funding years, bench models were conceptualized, fabricated, and proof tested to demonstrate metering, dispensing, and consolidating detonators in rapid motion.

SUMMARY

The objective of these projects was to design and build a pilot line for manufacturing detonators. This pilot line would be designed to manufacture and inspect detonators at a rate of 100 per minute while demonstrating the capability of producing at 1200 per minute. This would be accomplished by designing the pilot line with only a portion of the turrets required for the production system and placing a detonator into only every 12th position in the transport chain.

FMC Corp. was contracted to design and fabricate the pilot line. They designed the pilot line but never built the line due to the development of a multi-tooled detonator loader concept. A conceptual drawing of the pilot line is shown in Figure 1.

The design of the FMC pilot line for detonator production was similar to the Small Caliber Ammunition Modernization Program (SCAMP) Primer Insert Submodule. The production operations were to be performed by tooling mounted on a continuously rotating turret. The detonator cups would be moved from turret to turret by a cup carrier mounted on a continuously moving chain. Once a cup was placed into the carrier, it would not be removed until the assembly operations were complete. At each individual work station, the carrier would be aligned by self-centering collets on the chain. Explosive powders would be resupplied by auxilliary powder transport systems. The pilot systems were to be equipped with an automatic inspection module; however, this module was never designed.

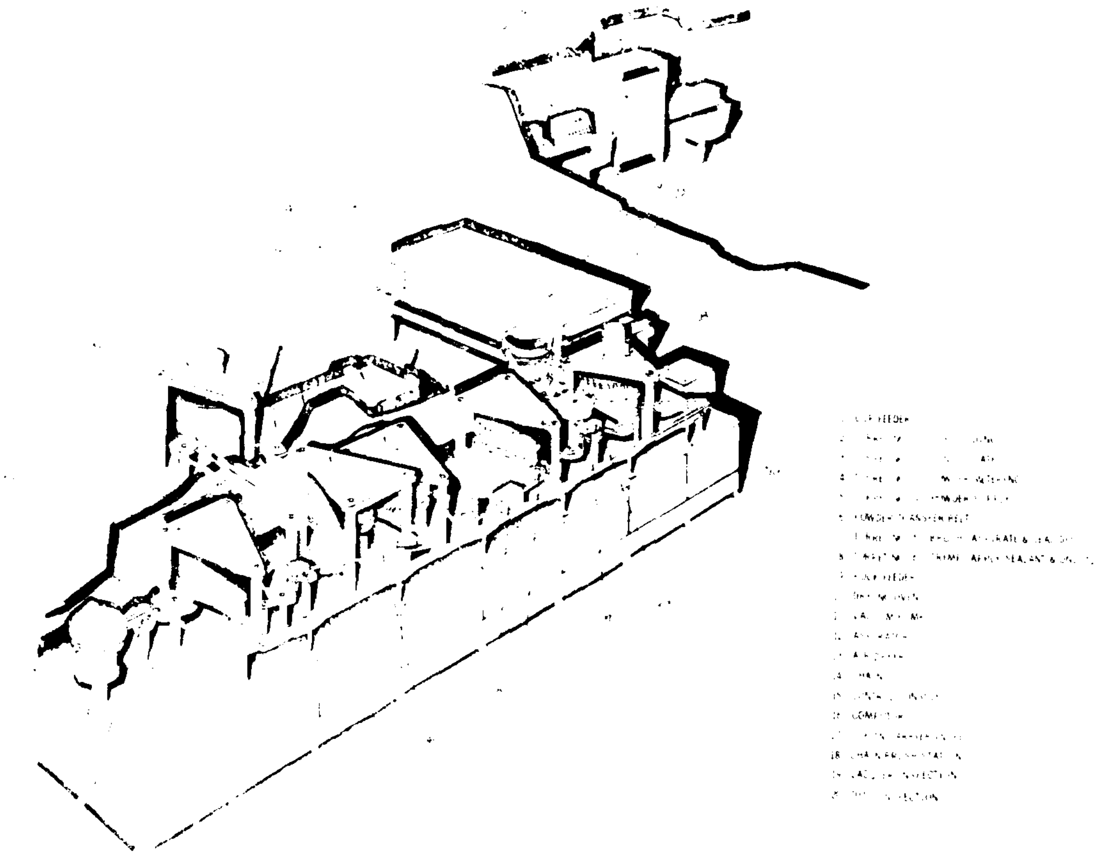


Figure 1 - Pilot Line Concept

BENEFITS

These projects designed a pilot facility for automated production of detonators. This facility was to show that the individual submodules could produce detonators at a rate of 1200/minute while the pilot system actually produced 100 detonators per minute. These projects advanced the state-of-the-art in detonator production technology in the areas of explosive metering, parts handling, process control and on-line sealing.

IMPLEMENTATION

The results of these projects were to be implemented through the construction of an automated pilot line for high speed production of detonators. However, prior to pilot line construction, a new concept for increasing the output of the current detonator loading machine was being investigated. This concept involved adapting an existing Iowa detonator loader to accept multiple tooled work stations. This increased the output of this machine by more than threefold. With the current mobilization rates, these multi-tooled Iowa loaders were more economical and required less development time. Therefore, the high speed loading concept was terminated. However, much of the technical data developed in these projects can be used in the development of auxilliary equipment to support the multi-tooled loader.

MORE INFORMATION

Additional information may be obtained from Mr. Paul Monteleone, ARRADCOM, AV 880-5389 or Commercial (201) 328-5389.

Summary Report was prepared by Joe M. Carter, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 577 4114, Subtask 23 titled, "Disposal of Methyl Nitrate from HMX and RDX Manufacture" was completed in June 1977 by the US Army Armament Research and Development Command at a cost of $136,000.

BACKGROUND

Project 577 4114 supports pollution abatement in connection with manufacturing, loading, and assembly operations at Army ammunition plants.

Subtasks are broad in scope and can cover one or many of the following areas: feasibility studies, process designs, bench scale, pilot plant, and demonstrations of processes. The purpose of this particular subtask was to conduct a feasibility study, prepare a complete process design, and demonstrate a pilot scale of a process to dispose of methyl nitrate. Methyl nitrate is a toxic and explosive by-product of the manufacture of RDX and HMX.

SUMMARY

A pollution problem existed at Holston AAP because of the venting of methyl nitrate to the atmosphere. Weak acetic acid (55-60%) left over from the nitrolysis reactions in the manufacture of HMX and RDX must be concentrated to glacial strength for recycle to the reactors and for feed to the anhydride manufacturing plant. The weak acetic acid is evaporated and further concentrated by azeotropic distillation. During the azeotropic distillation, some impurities concentrate in the n-propyl acetate phase, requiring venting. These impurities degrade the azeo solvent through hydrolysis and esterification reactions. The major impurity, methyl nitrate, can reach a concentration of 18-20% in the azeo solvent if the system is closed. Such a high concentration results in a loss of distillation efficiency. If the methyl nitrate concentration is allowed to exceed 50-70%, it becomes a sensitive explosive.

A process was developed to prevent the build-up of methyl nitrate and to safely dispose of it. A constant liquid bleed of 700-800 lbs a day keeps the concentration of methyl nitrate in the stills at a constant level. It was determined that the simplest and least expensive process for pollution free operation was the incineration of the entire liquid bleed.

It was not feasible to recycle any of the solvent. The incineration of this material did not present any safety hazards and it burned smoothly.

BENEFITS

Disposal of methyl nitrate provides an ecologically acceptable alternative to the practice of venting to the atmosphere which had been the traditional solution to the problem of methyl nitrate disposal. The cost of this method is fairly low.

IMPLEMENTATION

The following illustration, Figure 1, shows how this method has been implemented at Holston AAP. The process cost $50,000 to implement. The existing tar burners were easily adapted for incineration. The only hardware required for this process were pipes, pumps, and two storage tanks.

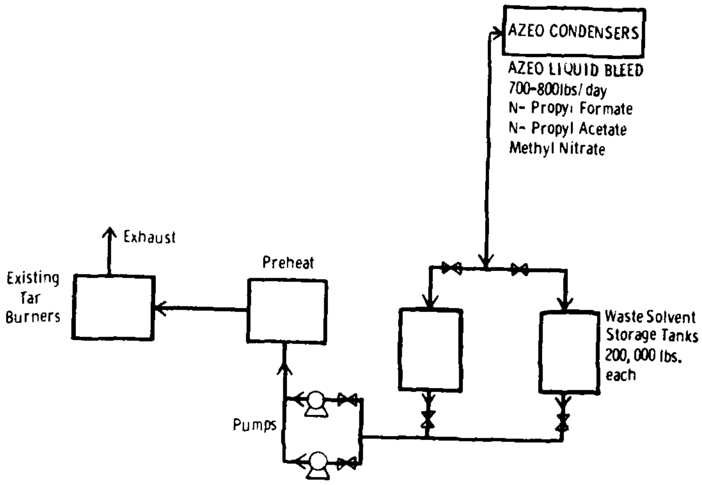


Figure 1 - Waste Solvent Incineration Process for Methyl Nitrate

MORE INFORMATION

Additional information on this project may be obtained by contacting Mr. E.A. Boyce at AV 880-4488 or Commercial (201) 328-4488.

Summary Report was prepared by Steve Albrecht, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 573 4139 titled, "Application of Radar to Ballistic Acceptance Testing of Ammunition (ARBAT)" was completed by the US Army Research and Development Command in July 1977 at a cost of $366,000.

BACKGROUND

Instrumentation available for acceptance testing of ammunition cannot provide sufficient ballistic data while attempting to track the round from launch to impact. Current procedures are laborious, costly, and fail to capture continuous, accurate data. The concept of a radar-based instrumentation system to provide ballistic data was studied under a prior year project. Feasibility was demonstrated and the overall system design completed. Fabrication of the antenna phase shifters was started.

SUMMARY

The objective of the entire ARBAT effort is to develop, build, test, and document an X-band phase/frequency scanning radar system for ballistic ammunition testing applications. The system will be capable of tracking a wide range of ammunition projectiles over most of their trajectories and provide complete accurate ballistic test data. The main thrust of this project was directed toward the design and fabrication of the antenna.

The antenna is a planar array design with an aperature of 10 ft x 12 ft. Beam scanning is accomplished by a combination of electronic and mechanical means. The beam is scanned in elevation by four-bit diode phase shifters. Azimuth scanning is by frequency variation and mechanical rotation of the array. The mechanical rotation capability is limited to a maximum of $\pm 170^{o}$. Development steps included fabrication and testing of individual critical items and assemblies to estimate full array performance. A nine element partial array was range tested prior to fabrication of the required 167 horizontal array elements and associated microwave elements. A front view of the antenna is provided in Figure 1.

BENEFITS

Upon completion of the ARBAT system, the following benefits will be realized:

(1) <u>Time Savings</u> - Test information will be available in real time. Due to improved testing capabilities, retesting will be greatly reduced.

(2) Savings in Equipment and Personnel - The total number of proving ground radars and operators will be considerably reduced.

(3) Reliability and Accuracy - The capability to track all rounds and collect accurate test data will be established.

(4) New Capabilities - Data not previously available, true velocity, trajectory events (ignition, burnout, accidental part loss, etc.) can be collected.

(5) Safety - Knowledge of ballistic performance will allow for the timely elimination of unsafe conditions and improve ammunition.

Figure 1 - Antenna Assembly Front Array View

IMPLEMENTATION

This individual project is part of the overall ARBAT effort. The objective, fabrication of the antenna, was accomplished. This component will become an integral part of the ARBAT system.

MORE INFORMATION

Detailed antenna specification and testing procedures are provided in the final technical report number 5059B, "MMT - Application of Radar to Ballistic Acceptance Testing of Ammunition (ARBAT) Phase B: Antenna Development/Fabrication" dated 30 September 1979. Contact Mr. O. Briedis, ARRADCOM, AV 880-4758 or Commercial (201) 328-4758 for additional information.

Summary Report was prepared by J.H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 574 4139, 577 4139, and 578 4139, titled, "Application of Radar to Ballistic Testing of Ammunition (ARBAT)" were completed by the US Army Research and Development Command in February 1980 at cost of $2470K, $190K, and $1565K respectively.

BACKGROUND

As a result of increasingly sophisticated testing requirements, the US Army initiated a program to develop an advanced radar system intended specifically for ballistic acceptance testing of ammunition. Existing instrumentation could not provide sufficient data while tracking the round from launch to impact. A study contract was awarded in 1971 to MITRE Corporation to investigate various alternatives and propose a system approach based on Government testing requirements. The system configuration concept is depicted in Figure 1.

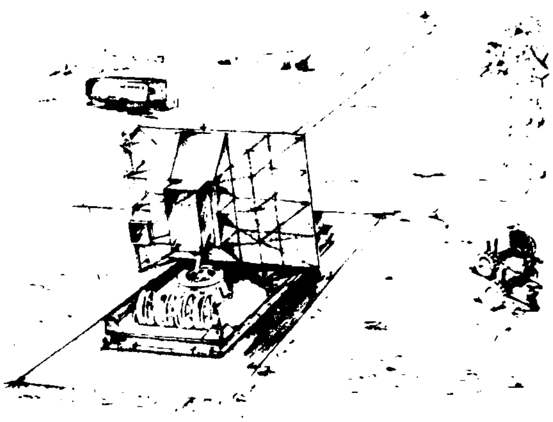


Figure 1 - System Configuration Concept

In 1972, a design study contract was awarded to ITT Gilfillan and a drawing package was developed. In 1973, Gilfillan was awarded a contract to fabricate an X-band phase/frequency scan antenna for the ARBAT application. A contract to complete the entire program was then awarded in October 1976 to ITT Gilfillan.

SUMMARY

The objective of the entire ARBAT effort is to develop, build, test, and document an X-band phase/frequency scanning radar system for ballistic ammunition testing. The design supports all currently produced and anticipated future ammunition items including artillery projectiles, mortar rounds, and rockets. The ARBAT system is of special importance to the modern, more sophisticated ammunition items including rocket assisted projectiles and improved conventional munitions.

During ballistic test, ARBAT is designed to measure all vital characteristics, such as: space position, true velocity, acceleration, drag, and radar cross section. Data outputs are available in real or near real time providing immediate feedback to ammunition designers and manufacturers thus permitting rapid elimination of problems and improvement of performance.

The test conducted during this program have verified the workability of the approach selected. Although all objectives were not met, additional required efforts were identified that will lead to a system which provides the necessary capabilities for future Government Proving Ground Test activities. The ARBAT radar system is capable of tracking artillery projectiles while providing real-time analysis, display of the trajectory characteristics, and permanent magnetic tape storage of the trajectory data for future off-line analysis.

BENEFITS

The ARBAT system provides the following benefits:

1. Time Savings - test information will be available in real time. Due to improved testing capabilities, retesting will be greatly reduced.

2. Savings in Equipment and Personnel - the total number of proving ground radars and operators will be considerably reduced.

3. Reliability and Accuracy - the capability to track all rounds and collect accurate test data will be established.

4. New Capabilities - data not previously available, true velocity, trajectory events (ignition, burnout, accidental part loss), etc., can be collected.

5. Safety - knowledge of ballistic performance will allow for the timely elimination of unsafe conditions and improve ammunition.

IMPLEMENTATION

The prototype system is currently being used at Yuma Proving Ground for back-up testing. Additional testing and enhancements are planned and will be completed before responsibility is transferred from the developing command, ARRADCOM, to the testing command, TECOM. Once ARBAT transitions, additional radar systems will be constructed and fielded.

MORE INFORMATION

A technical description of the ARBAT radar system, description of the system operation and operations procedures, and description and analysis of the Performance Demonstration Test results are provided in the contractor's final technical report, "Application of Radar to Ballistic Acceptance Testing of Ammunition" dated February 1980. Contact Mr. O. Briedis, ARRADCOM, AV 880-4758 or Commercial (201) 328-4758.

Summary Report was prepared by J.H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUACTURING METHODS AND TECHNOLOGY

PROJECI SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 573 4186, 574 4186, and 575 4186 titled, "Acceptance of Propellant Produced via the Continuous Process" were completed by the US Army Armament Command in September 1976 at costs of $517,100, $325,000, and $160,000 respectively.

BACKGROUND

The advent of high volume continuous production of propellant underscored the necessity to improve the accuracy and speed of assessment of propellant final product quality.

The existing Technical Data Packages (TDP) applicable to solid cannon propellant places a disproportionate emphasis on ballistic acceptance testing. The advantage of such testing is far outweighted by its disadvantages; such as, high cost of testing, long wait time for test to be performed and completed, and inability to discriminate between failures due to other causes, i.e. weapon, projectile, etc.

This effort addresses itself to the quality assurance aspects of the product, such as inspection and testing, from the continuous process standpoint.

SUMMARY

The objective of this project was to improve the accuracy and rapidity of assessing final product quality compatible with the continuous method of manufacturing. There were ten major areas of work accomplished by these three projects in support of the objective. Work accomplished: (a) provided Radford AAP with a computerized automated data acquisition and analysis system for closed bomb testing, (b) developed the Dynagun, a laboratory ballistic simulator for the 155mm M126E1 Howitzer, (c) developed a computerized data base of single base propellant production and test history, (d) provided mathematical models of the interior ballistics of the 175mm M86E1 and the 155mm M4A2 Propelling Charges, (e) developed rapid analytical techniques through the computerization of gas chromatography and the development of an accelerated chemical extraction method for chemical analysis of both dough mixer and extruded grains, (f) identified sampling port requirements in line for computer assisted single base line process as well as location and type of required off line analysis and test equipment, (g) provided necessary input to prepare a Technical Data Package for M1 propellant for the M4A2 Propelling Charge, (h) determined the effects of propellant parameters on ballistic performance through the production, testing and analysis of special

pilot lots of M1 propellant, (i) developed new techniques for propellant closed bomb evaluation, and (j) developed a complete preliminary Quality Assurance Plan for the continuous process which minimizes the need for ballistic firing.

BENEFITS

This project has provided proven relationships between ballistic performance and characteristics of single base propellants. It established new test techniques for rapid testing and analysis of propellants and a Quality Assurance Plan for the continuous manufacture of single base propellant. Cost savings are expected to be realized from improvements in acceptance testing, reductions in storage cost, and reductions in reject rate.

IMPLEMENTATION

The results of this project will be implemented in the form of a Technical Data Package for the procurement of single base propellant produced via the continuous process. ARRADCOM is the activity responsible for preparing the TDP.

MORE INFORMATION

Additional information on these projects is available from the Project Manager, Mr. Patrick Serao, ARRADCOM, AV 880-5364 or Commercial (201) 328-5364.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 570 4205 titled, "The Processing of Spent Acid from RDX/HMX Reaction for Recovery of Explosives and Acid" was completed by the US Army Armament Research and Development Command in September 1972 at a cost of $125,000.

BACKGROUND

RDX and HMX are manufactured at Holston AAP by suitable adaptations of the basic Bachmann Process. Hexamine, ammonium, nitric acid, and acetic anhydride are reacted under controlled conditions in an acetic acid medium to produce RDX or HMX in separate reactor systems. During nitrolysis and the filter/wash steps, large amounts of dilute acetic acid are generated. These dilute acids are recovered and reconstituted to glacial acetic acid by evaporative processes in which a primary distillation process is used to produce a solids-free distillate and an azeotropic distillation step to reconstitute the recovered aqueous acid to glacial acetic acid. The primary distillation process consists of five basic steps: (1) caustic neutralization of nitic acid, (2) acetic acid recovery by evaporation, (3) conversion of ammonium nitrate to sodium nitrate and residual explosives, (4) sodium nitrate recovery, and (5) ammonia recovery. The main disadvantages of this process are the high operating costs associated with step 2, the high costs for sodium hydroxide in step 1, and excessive steam consumption.

Therefore, a program was initiated to perform modifications that would reduce neutralization costs or reduce the evaporative load in the acid and/or by-product recovery streams which would offer significant savings in operating and material costs.

SUMMARY

The objective of this project was to identify potential improvement areas in the present acetic acid recovery process and to test modifications which offer cost or safety advantages over existing systems. To attain the objectives, various unit operations used in the acid recovery system were examined with bench-scale equipment, beginning with the treatment of incoming feedstreams to the recovery of acetic acid and the handling of by-product sludges.

Improvements for reducing both material and steam costs for processing spent acid were investigated and are reported in the following paragraphs.

The acetic acid content was increased from 60% to 80-90% in the spent acid in an effort to reduce the amount of water which had to be evaporated. This effort resulted in reducing the evaporation load for the primary evaporator, increasing the explosive load to the Acid Recovery area, and creating an imbalance between dilution liquor generation and usage rates.

Various neutralizing and causticizing agents were studied in an effort to find a less expensive material to accomplish nitric acid neutralization and destruction of explosives in the spent acid recovery process. Of the various alternatives, ammonia was satisfactory as a neutralizing agent and calcium hydroxide (lime) as a causticizing agent. The use of lime in the neutralization step resulted in sensitized, recovered explosives because of the presence of sulfate and silicate impurities. The combination of ammonia as a neutraizing agent and calcium hydroxide as a causticizing agent offered cost advantages relative to using sodium hydroxide.

The use of inorganic salts for partial vapor phase dehydration of the acetic acid-water distillate from the primary evaporator was explored. This resulted in the dehydration of acetic acid from 60% to 90%. Calcium chloride appeared most effective relative to magnesium acetate, calcium acetate, magnesium nitrate and calcium nitrate. The technique was not recommended due to salt regeneration cost and the tendency of the salts to lose water of hydration at process temperature.

The use of dilution was studied since the dissolved explosive load carried in spent acids could be reduced. A combination of dilution and cooling (-10 to +5°C) of spent acids precipitated 75-98% of the initial explosives. The use of dilution, however, resulted in a significant amount of water which increased the evaporative load.

Treatments with activated carbon in fixed beds were tested for their ability to remove dissolved explosives from spent acids. The adsorptive capacity of the carbon was higher in dilute (30%) spent acids than in stronger (60%) acids. Based on these results, the adsorption with carbon should be accomplished after the dilution step for maximum efficiency.

A counter current/liquid-liquid extraction method with n-propyl acetate was employed to reduce the evaporative load caused by the use of dilution. This method produced an extract containing about 96% of the available acetic acid in the feed-stream with 4-14% water and a raffinate containing relative small amounts of solvent and acid. A major disadvantage of this process was the distribution of essentially all of the explosives and traces of sodium and ammonium nitrate (about 80 to 160 ppm) in the solvent-rich phase (extract). Additional treatment of the extract would be necessary to remove the explosives and residual nitrates to acceptable levels before distillation of the stream to produce glacial acetic acid.

As an operation for treatment of primary sludge, the liquid-liquid extraction using n-propyl acetate was effective in recovering about 100% of RDX and HMX using a solvent to sludge ratio of 0.6 to 1 and three equilibrium stages. Concentrations of 80 to 160 ppm of ammonium nitrate and sodium nitrate were found in the extract.

Based on the results obtained during the laboratory phase, the number of processing steps involved and the inter dependency of the steps, additional laboratory work was required to further develop and optimize the final process before proceeding to a pilot scale. The approach was to evaluate the most promising results obtained previously on a bench-scale B line in a follow-on project.

BENEFITS

The results of this project find application in the spent acid recovery area at Holston AAP. However, proven cost reductions cannot be made until process changes are implemented into production operations.

IMPLEMENTATION

The aforementioned process changes cannot be considered for implementation into production operations until a follow-on effort is completed.

MORE INFORMATION

Additional information on this project is available from Mr. L. Sotsky, ARRADCOM, AV 880-2160 or Commercial (201) 328-2160.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 572 4220 and 573 4220 titled, "Continuous RDX Recrystallization Prototype Facility" were completed by the US Army Research and Development Command in November 1975 at costs of $750,000 and $811,000 respectively.

BACKGROUND

A prototype continuous Composition B production process (Line 1) was undertaken at Holston Army Ammunition Plant (HAAP) to modernize the manufacture of Composition B to "state-of-the-art" technology. The modernization would increase the capacity of Line 1 from 4,500,000 lbs/month to 7,500,000 lbs/month of Composition B. One of the major processing steps in the production of Composition B is the recrystallization of crude RDX. In order to convert to a continuous process, the present batchwise recrystallization had to be revised. Engineering and laboratory studies indicated that the same recrystallization equipment could be used if it was repiped for continuous recrystallization. In addition, a new solvent recovery system had to be provided to support the continuous recrystallization scheme.

SUMMARY

The overall objective was to establish continuous RDX recrystallization system to meet the production process requirements to manufacture 7,500,000 pounds of Composition B per month on Line 1.

Under the FY72 project, a design was prepared for the prototype continuous recrystallization process based on laboratory experiments performed at HAAP. The continuous process is described as follows:

The RDX slurry and cyclohexanone was fed semi-continuously into the first dissolver. The mixture in the first dissolver flowed by gravity into the second dissolver. The mixture then flowed into the first of six stills where the cyclohexanone was removed by distillation. The recrystallized RDX overflowed from the sixth still into a tank where the slurry was cooled from 100°C to 92°C. The slurry was then pumped to an in-line mixer to form a Composition A-7.

Other important design considerations included staying within the maximum 35,000 pound explosives load limit of the building and reusing the existing building (G-1) and equipment to the maximum extent.

After finalizing the design, a hazards analysis was conducted, existing equipment was modified for continuous operation, and equipment procurement was initiated. During the FY73 program, the equipment procurement, installation, and prove out of the continuous recrystallization process was completed. During April, May, and June 1974, the prototype was successfully operated to produce more than two million pounds of crude RDX. The material produced was of excellent quality with regard to particle size, melting point, color, residual acidity, and impact. However, solvent loss was higher than expected when compared to the standard batch process. This was due to additional water in the product slurry and the limitations on solvent removal by excessive foaming in the still system. Experiments performed indicated that the solvent recovery column was too small to handle the volume of solvent produced. Therefore, the solvent bearing water was pumped to the distillation system in Building G-4 for solvent recovery. Afterwards, the cyclohexanone was pumped back to G-1 for reuse.

Prove-out was restarted in 1975. The initial product produced contained small amounts of a sensitive explosive (alpha-HMX). Both laboratory and plant scale experiments were conducted to determine what factors caused two different HMX formations in the batch and continuous processes. The results indicated that alpha-HMX production correlated with high distillation rates and low feed rates. Because of the potential hazard created by producing alpha-HMX, the continuous recrystallization process had to be abandoned. However, in order to support the prove-out of the entire Line 1, additional work was directed to the concept of an automated batch recrystallization process even though a reduced production rate would result. Various modifications were accomplished in the G-1 building in order to convert to the batch system.

Figure 1 shows the flow scheme for the automated batch system. The RDX slurry and cyclohexanone was fed into both dissolvers. The dissolvers were capable of discharging batches into each of the four stills. The distillate, an azeotrope of cyclohexanone and water, was separated in the condensors where cyclohexanone was returned to be reused in the process. After distillation, the recrystallized RDX batch from each still was pumped to the surge tanks where the recrystallized RDX overflowed to the cooling tank (92^{o}C). The slurry was then pumped to an in-line mixer to form Composition A-7. The system was proved out and met all operating requirements and produced acceptable RDX but at a lower production rate. In order to meet the production rate, new equipment was to be designed and installed in G-1 which would increase its capacity. The feasibility of the design concept for automated batch was fully demonstrated.

BENEFITS

An automated batch recrystallization process was designed and successfully operated to produce recrystallized RDX of acceptable quality.

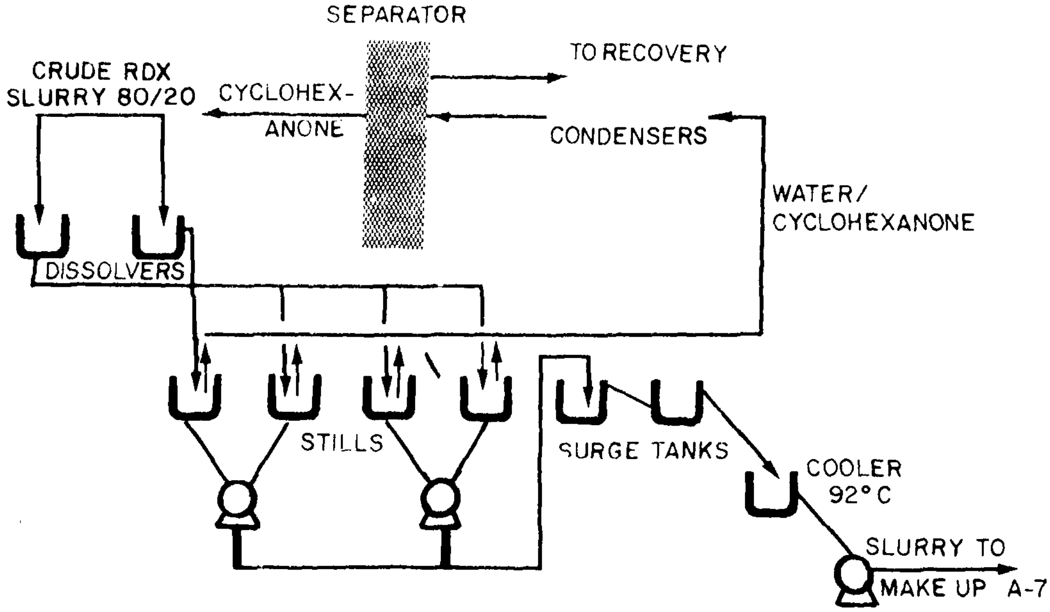


Figure 1 - Flow Sheet for Automated Batch Recrystallization of RDX

IMPLEMENTATION

The automated batch recrystallization process was installed and successfully operated at Holston AAP with a capability of producing four million pounds of Composition B per month. Engineering data developed during this effort is being used in the design of a recrystallization system which will be capable of increasing the production capacity to 7.5 million pounds of Composition B per month.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. Steve Dollman, AV 880-2160 or Commercial (201) 328-2160.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 577 4252 titled, "Improve Present Processes for the Manufacture of RDX and HMX" was completed by the US Army Research and Development Command in February 1980 at a cost of $884,200.

BACKGROUND

This effort was a continuation of process modifications to improve the present methods of manufacturing RDX and HMX compositions. The FY7T effort under this project emphasized investigating the use of n-octane in lieu of toluene as the solvent in the preparation of Composition C-4. Various methods of coating RDX with Composition C-4 binder were also investigated. This work was continued under this project year.

Earlier efforts indicated that the use of reaction promoters (chemical additives) can enhance the efficiencies of the RDX/HMX process and improve yields. Additional work was needed toward evaluating potential reaction promoters on a laboratory scale.

SUMMARY

The objectives of this effort were to develop an improved process for the production of Composition C-4 and to evaluate the use of reaction promoters to improve the efficiency and yields of the RDX/HMX process. The approach was to investigate the development of the C-4 process and the effects of reaction promoters through bench scale studies.

The first step in developing an improved process for Composition C-4 was to determine the physical characteristics such as shelf life, viscosity, and drying curves of Composition C-4. Then the initial sub-process, lacquer preparation, was examined for the dominant factor controlling the dissolution of Vistanex into toluene. The controlling factor was found to be the minimum dimension of the block of Vistanex whereas the temperature of toluene and degree of agitation caused only slight effects.

The next item investigated was an alternate solvent for dissolving Vistanex N-octane was found to provide a higher dissolution rate than toluene for Vistanex and in addition, was non-carcinogenic. N-octane was then evaluated in the manufacture of C-4 and showed no difference between C-4 made with toluene.

Various techniques were examined for coating the RDX with Composition C-4 binder. The first coating technique evaluated was the "Wabash" method which

consisted of coating the RDX with the highly viscous, solvent-free binder. However, since this operation required a large amount of energy, some solvent was added to the binder. This resulted in easier mixing but high temperatures were required to remove the solvent.

Other coating techniques involved the evaluation of slurry methods. Based on the laboratory bench studies, a dual precoat process was proposed as the optimum process for the manufacture of Composition C-4. A flow sheet for the proposed process is shown in Figure 1.

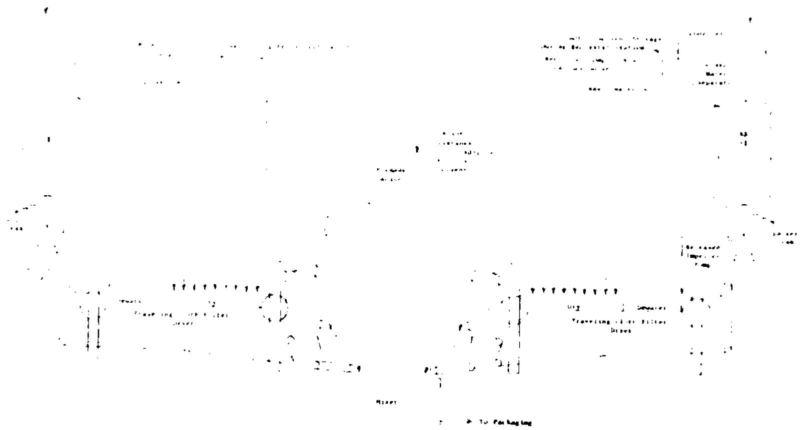


Figure 1 - The Dual Precoat Process for Composition C-4

In this process, both Class 1 and Class 5 RDX were recrystallized in their own respective stills. The premade lacquer was charged to coat each batch of RDX with 9.5% binder. The batch was then heated to remove the solvent-water azeotrope and then cooled and pumped to a separate facility for dewatering/drying. A traveling belt filter with two zones, one for dewatering and one for drying was used prior to blending and packaging.

The task of studying reaction promoters proceeded towards the determination of potential additives, the compatibility of promoters with the nitrolysis medium, optimization studies for promoter selection, and final laboratory scale prove-out of selected promoters. Reaction promoters tested were boron trifluoride, nitrous oxide, sodium nitrate, paraformaldehyde, ammonium acetate, acetamide, acetonitrile, lithium nitrate, and hexamine. The results of the tests indicated that there were no improvements in RDX yields provided by the addition of the reaction promoters to RDX batches. The HMX yields, however, were increased by the addition of paraformaldehyde and hexamine to RDX batches. This increase was not due to greater conversion efficiency of hexamine to HMX but to an increase in the poundage of product per batch.

BENEFITS

This project developed a dual precoat process for the preparation of Composition C-4 which will result in increased production capacity. N-octane was selected as a replacement for toluene, a suspect carcinogen, as the Composition C-4 lacquer solvent.

IMPLEMENTATION

The proposed dual precoat process will be evaluated in the pilot plant portion of MMT project 580 4449.

MORE INFORMATION

Additional information on this project is available from Mr. S. Dollman, ARRADCOM, AV 880-3717 or Commercial (201) 328-3717.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 576 4285 titled, "TNT Equivalency Testing in Support of Safety Engineering for Ammunition Plants" was completed by the US Army Armament Research and Development Command in June 1978 at a cost of $325,000.

BACKGROUND

In the mid 60's, the US Army Materiel Command initiated a program to upgrade the safety standards of new and existing ammunition plants. In support of this program, design standards were developed for hardening protective structures to withstand the effects of the detonation of high explosives. Design and safety engineers required data pertinent to the maximum strength of a blast wave that may originate from any of the explosive or deflagratable materials present in a plant. Since blast parameters were not available from the literature on certain explosives and propellants, efforts were needed to establish TNT equivalencies of these materials. By utilizing this data, significant cost savings could be achieved by avoiding the overdesign of structures and safety of personnel improved by the installation of adequate blast protection.

SUMMARY

The objective of this effort was to develop data such as peak pressure and total impulse from blast measurements on a variety of explosives and propellants. This data was converted to TNT equivalency and subsequently utilized in the design of structural walls for facilities in Army ammunition plants.

Tests were conducted on a variety of explosive and propellant compositions in configurations that existed in current process lines at Army ammunition plants. These tests resulted in the establishment of pressure and impulse curves from the materials that were detonated. From these curves, TNT equivalencies were calculated and a technical report prepared for each material tested. The following information summarizes the results for each material tested:

<u>M26E1 Propellant</u>. Experiments were performed with M26E1 multiperforated propellant in subscale and full-scale shipping drum containers and mocked-up full-scale drop plug buggies, dryer beds, and blenders as shown in Figure 1. Blast output was measured and TNT equivalency computed based

upon a comparison with the explosive blast output of a surface burst of a hemispherically shaped TNT charge. Results indicated that the propellant was able to generate peak pressures and positive impulses greater than those produced from an equivalent weight of TNT. The blast output from the propellant was found to be dependent on the original configuration. TNT equivalency values were determined for the propellant in four in-process manufacturing configurations.

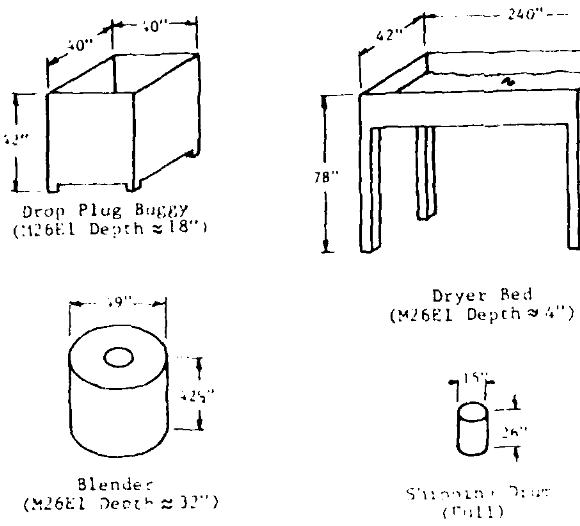


Figure 1 - Test Configurations for M26E1 Propellant

BS-NACO (Butyl Stearate Navy Cool) Propellant. Experiments were performed with BS-NACO propellant in subscale and full-scale shipping/storage drum configurations and in full-scale conically shaped feed hopper configurations to determine the air-blast pressure and positive impulse resulting from the detonation of the material. Theoretically, a given pressure will occur at a distance from an explosion that is proportional to the cube root of the energy yield. Peak pressure and positive impulse were measured in the scaled distance range of approximately 2 to 25 ft/lb$^{1/3}$. TNT equivalency curves for both pressure and impulse were developed as a function of scaled distance. Based on the test results, BS-NACO propellant should be considered QD Class Two Material while in-process.

Composition A5. Peak blast overpressure and scaled positive blast impulses were measured for Composition A5 using configurations that simulate bulk handling of material during processing and shipment. Quantities of 11.34, 22.7, and 27.22kg were tested in orthorhombic fiberboard boxes, and 68.04kg was detonated in a cylindrical fiber shipping drum. High-explosive equivalency values for each test series were obtained as a function of scaled distance by comparison to known pressure, arrival time, and impulse characteristics for hemispherical TNT surface bursts. The equivalencies were found to depend significantly on scaled distance with high values of 140 to 500% at scaled distances in the range from 1.19 to 15.87 m/kg$^{1/3}$.

Equivalencies as low as 100% were obtained at intermediate distances. Within experimental error, both peak overpressure and positive impulse did scale as a function of charge weight for all quantities tested in the orthorhombic configuration.

M10 Propellant. Peak, side-on blast overpressure, and scaled positive impulse were measured for M10 single-perforated propellant using configurations that simulate the handling of bulk material during processing and shipment. Quantities of 11.34, 22.7, 45.4, and 65.8 kg were tested in orthorhombic shipping containers and fiberboard boxes. High explosive equivalency values for each test series were obtained as a function of scaled distance by comparison to known pressure, arrival time, and impulse characteristics for hemispherical TNT surface bursts. The equivalencies were found to depend significantly on scaled distance with higher values of 100-150% (pressure) and 125-350% (positive impulse) for the extremes within the range from 1.19 to 3.57 $m/kg^{1/3}$. Within experimental error, both peak pressure and positive impulse did scale as a function of charge weight for all quantities tested in the orthorhombic configuration.

BENEFITS

This project provided TNT equivalency data which when used with AMCR 385-100 and TM5-1300 enables the designer to design walls that will safely resist the blast effects of an accidental explosion of the materials tested. Considerable cost savings can be realized through the use of the data developed.

IMPLEMENTATION

The results published in technical reports were distributed to AAP's, Corps of Engineers, other design agencies, and various other safety echelons for use in conjunction with TM5-1300. The equivalency results using TNT as a basis can be converted readily to overpressures and impulses since the design data in the manual is based upon TNT curves. This enables the designer to calculate loads on protective walls readily for the energetic material in question.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. J. Marsicovete, AV 880-3906 or Commercial (201) 328-3906.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 577 4341 titled, "Improved Nitrocellulose Purification Process" was completed by the US Army Armament Research and Development Command in March 1979 at a cost of $165,000.

BACKGROUND

When nitrocellulose (NC) is used in the manufacture of gun propellants, it must be purified to exacting standards to insure chemical and physical stability during long periods of storage. Purification of NC requires the removal and neutralization of acidic traces that remain after the nitration operation. The current method, see Figure 1, for purifying NC is a World War I vintage batch method which involves numerous transfers and heating cycles of each batch processed. In this batch method, 18-24,000 pounds of NC are collected in huge tubes and subjected to a series of washing and boiling operations. After this series of operations, the NC is transferred to a different building where it is milled to a specified size and chemically neutralized (poached). Finally, the NC is transferred to another building for final neutralization and retention for eventual blending into specified compositions. The boiling through blending procedure requires approximately 148 hours and comsumes immence quantities of water and steam. In the interest of establishing a more cost effective and energy efficient operation, an improved NC purification process was proposed.

SUMMARY

This project was to investigate a number of existing methods for potential application to the purification of NC and from these methods, select one for further development and optimization. A multi-directional approach was used to attain the project objective. Alternatives for purifying NC were examined, a different technique of milling the NC fibers was tried, and different types of processing equipment were surveyed.

It is possible to remove acidic traces from NC fibers by swelling the fibers with a solvent. The swelling increases the surface area and enhances the flow of acid through the fiber and water is used to carry the acid away. An acetone-water mixture was used to test this principle. Removing the acid was successful but this technique changed the viscosity of the NC and it fell below the acceptable level. Therefore, this procedure was eliminated from further consideration.

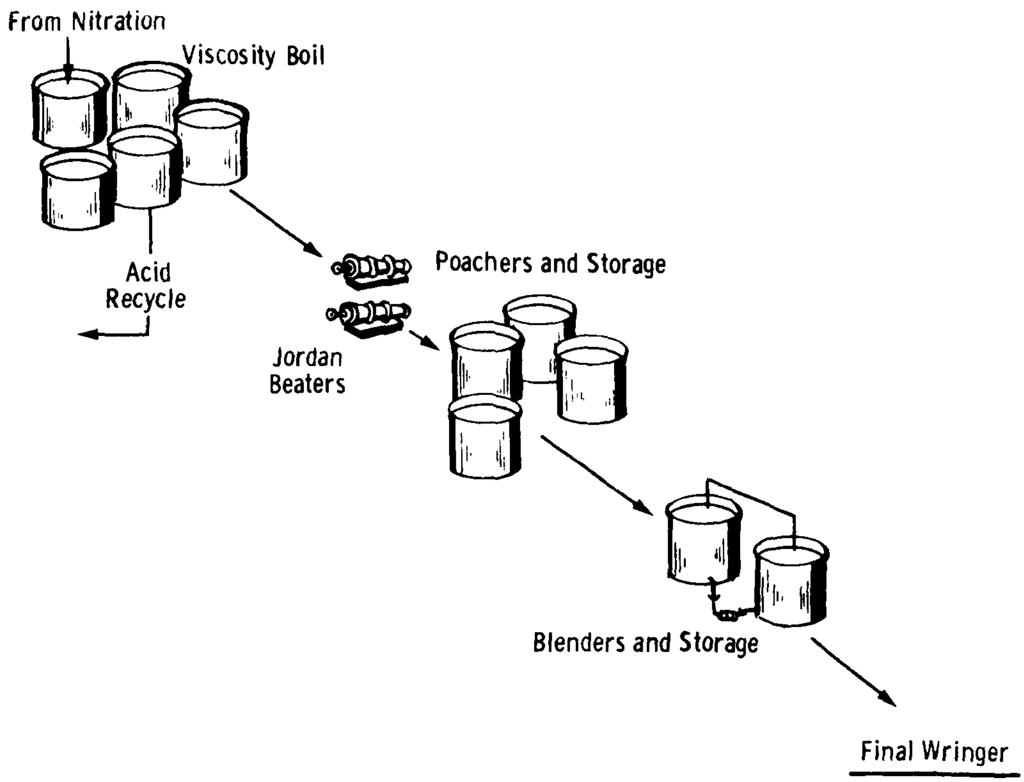


Figure 1 - Principal Operations in the Batch Process for NC Purification

The effects of cutting the NC fibers prior to boiling treatments was investigated on a bench scale. A Waring type blender was used to reduce the size of the fibers. These tests showed that there was no noticeable changes between the cut or uncut fibers when the boiling period was varied. Boiling was done in water, water-acetone, and finally water and soda-ash. It was concluded that even though this small type of cutter did not effect boiling periods, the tests would have to be repeated at a larger scale using an attrition mill to yield more conclusive results.

Purifying NC while under pressure and in a continuous stream was considered. Only one system was found that was considered to be safe enough to handle an explosive material and achieve the desired results. This system was the "Conicell" which is manufactured by Moser Processing, Corseaux, Switzerland. Discussions about the design alternatives of a prototype unit were initiated with Moser Processing. The design selected provides sufficient flexibility to evaluate process alternatives. The unit will carry a 10% NC slurry with a residence time of 45 minutes at a rate of 2000 pounds per hour. The design allows for acid boiling in the first part of the unit, followed by soda-ash injection and poaching in the last part. A capability for the evaluation of continuous controlled pH purification was included.

BENEFITS

The state-of-the-art for the purification of NC is being advanced. With the successful completion of the prototype evaluation, a method which requires less energy and floor space will be available.

IMPLEMENTATION

The results of this project were used to specify a prototype purification unit for purchase and evaluation with funds provided by follow-on projects.

MORE INFORMATION

Additional information about this project may be obtained by contacting the project officer, Mr. Bernard D. Strauss, AV 880-3014 or Commercial (201) 328-3014.

Summary Report was prepared by Andrew Kourco, Jr., Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 57T 4457 titled, "Multi-Tooled Iowa Detonator Loading Machine," was completed by the US Army Armament Research and Development Command in December 1979 at a cost of $332,000.

BACKGROUND

With the advent of Improved Conventional Munitions, the requirement for non-electric detonators increased to 100 million/month at mobilization and 100 million/year in peacetime. Current detonator equipment is World War II vintage which requires large facility space and is highly labor intensive. Because the development of high speed loading equipment was lagging, the concept of multiple tooling the existing loader design became viable.

SUMMARY

The objective was to increase the output of an Iowa Detonator Loader to 150 units/minute. This was to be accomplished by retrofitting an existing Iowa Detonator Loader with a set of multiple level tooling. A study done prior to the design effort concluded that quad tooling should be the optimum tooling level. Mason & Hanger - Silas Mason Co., Inc., operating contractor of the Iowa AAP, was contracted to perform the work.

The existing Iowa Loader, and thus, the multi-tooled loader, are both indexing dial machines. These machines consist of 24 equally spaced tooling stations. Detonators are transferred from one station to another by an index table. Index table motion and alignment is accomplished via cam followers. The multi-tooled Iowa Loader is shown in Figure 1.

During the redesign effort, numerous changes were made to the original machine to accommodate the quad tooling. The six inch center column was replaced with a 12 inch center column. The cam was extensively redesigned in an attempt to increase consolidation forces. The existing cam allowed 30° dwell, 185° up-stroke, and 145° approach. The redesigned cam has 30° dwell, 145° up-stroke, and 185° approach. This increased the consolidation time by 77% over the existing machine. Control of consolidation and crimp forces were changed to hydraulic in lieu of spring. This allowed easier monitoring and adjustment. Other detonator loaders used manual packout. This prototype machine automatically places the detonators into trays and sends the trays to an inspection station.

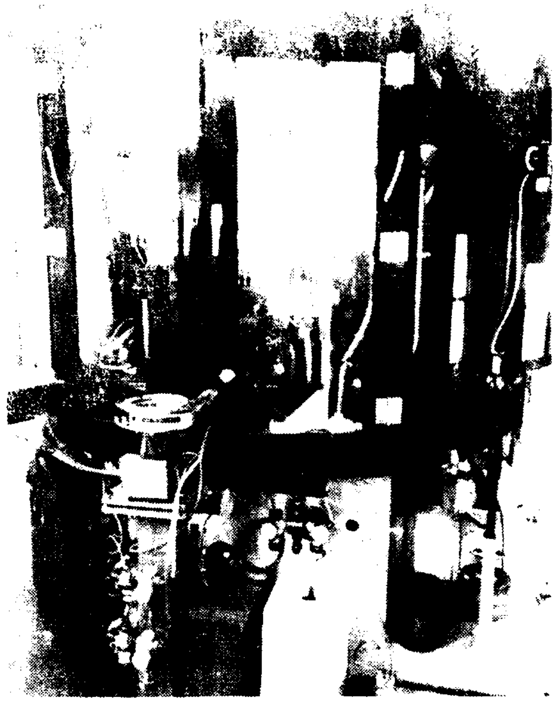


Figure 1 - X4 Series Iowa Loader with Shielding, Powder Guide Installer Area

Machine operations are controlled by a process controller built around a Motorola 6800 microprocessor. This unit provides both supervisory and data acquisition functions. Analog devices provide numerical data to the process controller on the quality of each detonator.

Early during the debug phase of the prototype machine, a 40 hour RAM test was run. During this test, production rates as high as 23,000 per shift were achieved versus a historical average of 12,000 per shift for a single tooled machine. Since this test, rates as high as 38,000 per shift have been achieved during inert production. It is anticipated that 40,000 per shift can be achieved.

BENEFITS

This effort modified an existing Iowa detonator loader to accept quad-tooling. The benefit of this concept is the processing of four times as much material each cycle. It is anticipated that once fully debugged and adjusted, a 40K/loader/shift production rate can be achieved versus a 12K/loader/shift for a single tooled loader. Utilizing this concept in future facilities will reduce equipment investment by $900K for machines needed to meet mobilization requirements. It can also reduce peacetime operating cost by $1.[illegible] million per year.

IMPLEMENTATION

A separate effort has been initiated to design ancillary equipment for the multi-tooled loader. This equipment will handle inspection and packout functions. Because of the increased output of the multi-tooled machine, manual inspection and packout create a bottleneck. Thus, the success of the multi-tooled program is dependent upon the development of the ancillary equipment.

Six multi-tooled loaders are currently being built for installation in Iowa AAP's new detonator loading facility. Future facilitation at Iowa AAP, Lone Star AAP, or Kansas AAP will include a mix of single and multi-tooled loaders.

MORE INFORMATION

Additional information may be obtained from Mr. Paul Monteleons, ARRADCOM, AV 880-5389 or Commercial (201) 328-5389.

Summary Report was prepared by Joe M. Carter, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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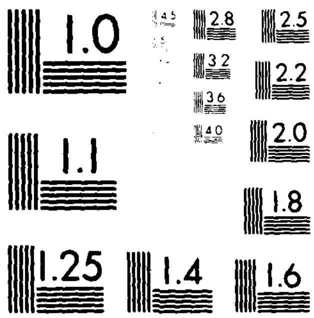

MICROCOPY RESOLUTION TEST CHART

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MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 575 4600 titled, "Prototype Equipment for Production of Cartridge, 105mm, APERS-T, M494 Components" was completed by the US Army Armament Readiness Command in June 1977 at a cost of $180,000.

BACKGROUND

A need existed to provide a high rate of production and automatic inspection of flechettes used in the 105mm APERS-T, M494 projectile. The previous production rate was to be increased by four times. Manual inspection of the high volume of flechettes was a labor intensive operation resulting in excessive costs for the items.

SUMMARY

The work for this project was performed by two contractors. AAI Corporation was to develop and build the flechette manufacturing machine and Conrac Corporation was to develop and build the inspection machine. AAI constructed and built the flechette manufacturing machine and completed an eight hour trial run in Jan 1977. The flechettes that were produced seemed to meet all drawing and specification requirements thus the feasibility to produce at a considerable cost savings was demonstrated. An automatic system that was designed to inspect 300 flechettes per minute was designed, built, and partially checked out when the project funds were exhausted. The machine was crated and shipped for storage at ARRADCOM without completing the effort.

BENEFITS

This project resulted in a machine that can increase the production of flechettes by four times the current rate. An inspection machine was also built; however, this machine did not become operational.

IMPLEMENTATION

Since there is no requirement for flechettes, the equipment that was developed was placed in storage and has not been used for production.

MORE INFORMATION

Additional information concerning the results of this project can be obtained from Mr. D. Jones, ARRCOM, Rock Island Arsenal, AV 793-3204 or Commercial (309) 794-3204.

Summary Report was prepared by Hal Weidner, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 571 6413 titled, "Hydraulic Size Classification Facility for Ball Propellants" was completed in August 1975 by the US Army Armament Command at a cost of $170,000.

BACKGROUND

The Government screening facility for ball propellant was built in 1954. It has three separation lines, each consisting of a series of seven screens. They are shaken in a eccentric motion as water is sprayed over the screen surface to reduce adhesion between the ball powder particles. Product from one screen falls to another screen as shown in Figure 1.

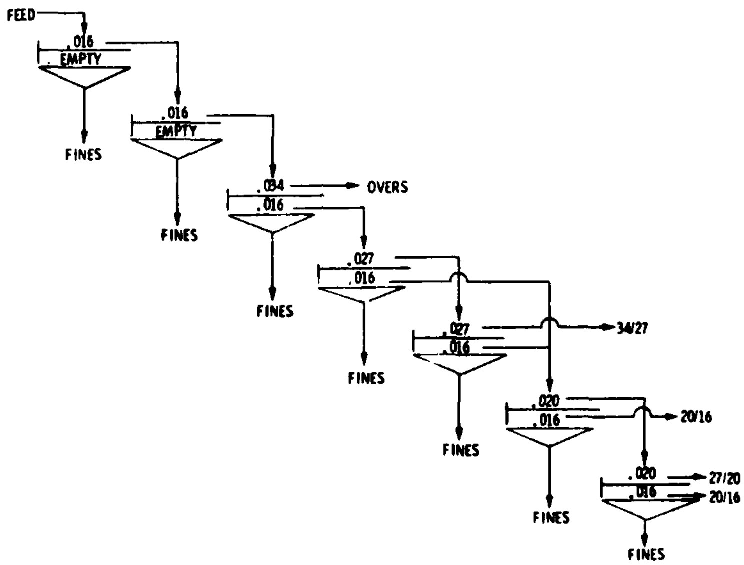

Figure 1 - Present Screening Facility

This method of separation has several disadvantages: (1) downtime for routine maintenance on this old equipment averages 30% as the entire line must be shut down to repair any one screen, (2) the maximum capacity of the facility is only about two-thirds of the required Mobilization Rate, (3) excessive water consumption because no provisions for recirculation have yet been made. Other problem areas include excessive noise level, personnel exposure to heavy moving equipment, and contamination of effluent waste water.

SUMMARY

The purpose of this study was to investigate methods of removing the bottleneck at size separation, thereby increasing production capacity. Three possible methods of increasing the output of the present size separation facility were considered.

Installation of Additional Screens. To meet the projected mobilization rate for Ball Powder production, an additional ten decks of screens would be needed to supplement the twenty-one now in use. This scheme would require a considerable capital outlay for a structure to house the equipment as well as the additional screens. Economic considerations as well as the aforementioned limitations of this type of screening process made it desirable to search for a new approach to the problem.

Centrifugal Size Separation. Preliminary experimentation with hydroclones demonstrated a high throughput capability but the sharpness of size separation with these units was insufficient to warrant further study.

Hydraulic Size Classification. Continuous size separation was effected by controlling the flow rate of a rising column of water. Smaller particles suspended in the rising column of water were carried upward and flow over the top while larger particles were drawn off at the base of the unit. This process has been used extensively in the mining industry to remove waste from ore by differences in specific gravity.

This latter approach appeared to offer the best prospect for improving the present size separation facility. Two modes of incorporating hydraulic classification were considered. The first would involve the use of hydroclassifiers to remove only the fines from the feed stock. The second mode was extensive substitution to separate the entire product into usable particle size ranges.

The main conclusion of the study was that hydraulic classifiers are capable of separating ball powder propellant into the desired size ranges with one exception. The 10/16 (thousands) size range will need to be classified further to meet current specifications.

BENEFITS

Removal of fines alone will provide a 50% increase in present size separation capability thus meeting mobilization requirements. More extensive use of hydroclassifiers would replace the present 21 screens with a maximum of six screens resulting in savings of $140,000/year (1974). Twelve separating columns sixteen inches in diameter would be required, four for removal of 20/16, three for separation of 27/20 from 34/27, and five necessary for removal of fines. The total capacity outlay was estimated at $160,000 (1974).

As a result of these favorable economics, it was recommended that a system of twelve hydraulic classificator columns and a maximum of six mechanical screens replace the 21 mechanical screens at the time of modernization as shown in Figure 2.

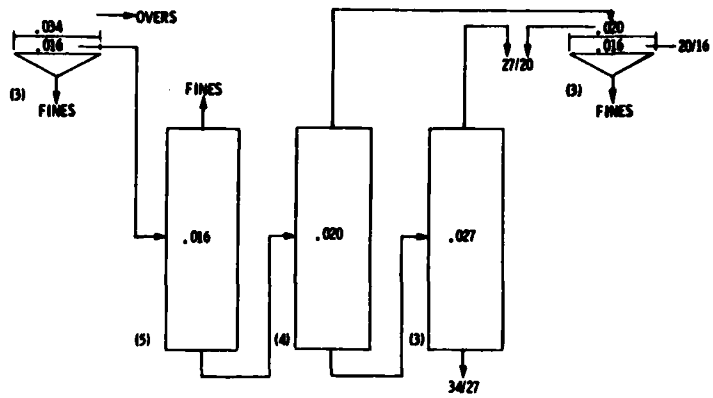

Figure 2 - Recommended System for Hydroclassification of the Entire Product W/Secondary Classification of 20/16 By Screening

IMPLEMENTATION

Ball propellant production was discontinued at Badger in the spring of 1975. Hence, the recommendations of this project were not implemented directly. A combined system of hydraulic classifiers and mechanical screens is being studied further as a part of projects 57X 6596 - Ball Propellant Pilot Plant Studies.

MORE INFORMATION

Additional information may be obtained from Mr. Robert M. Pizzola, AV 880-2265 or Commercial (201) 328-2265. A final report titled, "Hydraulic Size Classification Facility for Ball Propellants" was published in September 1974 by Olin Corporation, Baraboo, WI 53913, Technical Report TD-128.

Summary Report was prepared by W.R. Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

NON-METALS

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project E78 3587 titled, "SLUFAE Rocket Motor" was completed by the US Army Mobility Equipment Research and Development Command in December 1979 at a cost of $210,000.

BACKGROUND

The SLUFAE system requires a high quality, fast burning rocket motor in order to achieve necessary free-flight accuracy. Manufacture of the motor requires precise grinding and specialized batch mixing of a highly viscous propellant with a limited pot life. The propellant must be accurately metered into horizontal spincasting stands and spin cured under closely controlled conditions. Successful manufacture of the motors had been accomplished on a laboratory scale. It was necessary to scale-up to projected production rates and to develop sufficient documentation to permit production of high quality SLUFAE motors by government or commercial facilities.

SUMMARY

The principal objective of this project was to investigate the propellant ingredients and process variables in order to extend the useful pot life of the mix prior to casting. A minor objective was to improve the gelling characteristics of the mix to decrease the curing time required. The pot life extension would result in a longer time during which propellant could be injected into the motors while a quick gel would allow more efficient use of the spin cast equipment.

The current SLUFAE propellant is a hydroxy-terminated polybutadiene (HTPB) formulation with an effective pot life of approximately three hour. The spin cast process limits the maximum casting viscosity to 14 kilopo . The exact gel time is undefined; however, gelation occurs within a 16 hour curing period while spinning the motors horizontally at 150 RPM.

Initially, one-pint mixes were used to establish a baseline mixing and testing procedure and to define propellant parameters such as maximum casting viscosity, casting temperature, pot life, and time-to-gel. The following procedures were established: the propellant was mixed at a temperature of 127-129°F; the water jacket temperature was 144°F. The end-of-mix viscosity (EOM) was also measured at the propellant temperature. After EOM, the propellant was stored at 110°F, during which time the viscosity was measured hourly. Five hours after EOM, a cast speciman of propellant,

nomially 0.3-inch thick, was removed from the 110°F oven and stored in a 140°F oven. This represented the end of a five-hour casting period and the beginning of a 140°F gelation cure cycle. After a two-hour gelation period in the 140°F oven, a 0.3-inch thick propellant speciman was subjected to a slump-test by standing the mold vertically and observing the slump over a five-minute period at 140°F, see Figure 1. Less than 1/32 inch slump was interpreted as a gelled propellant. Finally, cured propellant uniaxial tensile properties and burning rates of new formulations were measured as necessary.

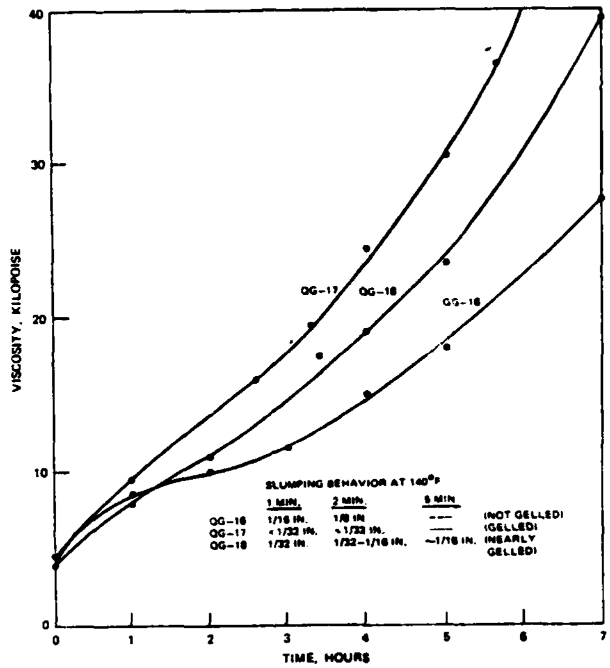

Figure 1 - Effect of Triphenyl Bismuth Percentage on Viscosity (QG-16=0.005%, QG-18=0.015%, QG-17=0.025%)

Following the establishment of the mixing and testing procedures, the batch sizes were scaled up to five-gallon mixes and then to larger production size mixes. The scale-up was intended to verify processability and characteristics on a production-size mix and to cast motors for verification of ballistic performance.

This work demonstrated that the SLUFAE propellant pot life could be extended to at least six hours by replacing two percent of the binder with dioctyl adipate plasticizer. It also showed that the addition of a small percentage (0.005%) of triphenyl bismuth to the plasticized formulation would prevent an increase in the propellant gel time over that of the standard SLUFAE formulation. It was also discovered that a purer form of aluminum oxide would result in an increased pot life.

A limited number of motor static firings from one scaled up production mix indicated that motor ballistic performance was not adversely affected.

BENEFITS

This project resulted in the doubling of propellant pot-life to six hours. This result was achieved without extending the centrifugal spin curing time required at elevated temperatures. Cost savings of approximately \$30 per motor have been estimated to accrue on production rates of 1600 motors per month.

IMPLEMENTATION

These procedures will be implemented in the initial production tests at Longhorn Army Ammunition Plant that are scheduled for 1Q-2Q FY82.

MORE INFORMATION

Additional information on this project may be obtained by contacting Mr. William V. Millman, AV 354-4272 or Commercial (703) 664-4272.

Summary Report was prepared by Andrew Kource, Jr. Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 174 8091 titled, "Advanced Adhesives for Transparent Armor for Army Aircraft" was completed by the US Army Aviation Research and Development Command in October 1979 at a cost of $202,000.

BACKGROUND

The need for improvement in helicopter windshields has been identified and well documented for some time. Needed improvements include increased service life, enhanced ability to withstand bird strikes, greater resistance to small arms fire and ordnance fragments, and lower cost, all without sacrifices in optical properties. Helicopter windshields, almost without exception, are composed of a monolithic sheet of acrylic. This material is quite soft and easily scratched or abraded by cleansing agents, windshield wipers, and soil thrown onto the surface by the rotary wing airflow. Spalling also occurs from larger items impacting the plastic or from ballistic impact.

Many of these problems can be solved by using high performance glass/plastic composites. Recent advances in the state-of-the-art have made such composites possible. Scratching is reduced by the use of a glass outer ply and spalling can be reduced or eliminated by using a polycarbonate inner ply. Current film adhesives such as PVB used for laminated windows, however, do not yield optically acceptable bonds between glass and polycarbonate. Therefore, to reduce costs, make an acceptable product and extend service life of the glass/plastic composite, improved interlayer systems are desired.

SUMMARY

The objective of this effort was to provide a manufacturing technology and production standard to bond glass to polycarbonate with film adhesives for transparent armor applications in helicopters and similar aircraft. Cast in place adhesives, while otherwise satisfactory, are not suitable for use from a cost point of view.

Prior work studied four candidate materials for scale up production to actual windshield configurations. The goal was to select the optimum combination of ballistic, optical, and thermal properties. In this project, a contract was let to build full-size UH-1 helicopter windshields. Four sets, two each of two different constructions, were made and tested. The two types chosen are shown in Figure 1. These windshields were then to be evaluated optically and each construction subjected to thermal testing under load.

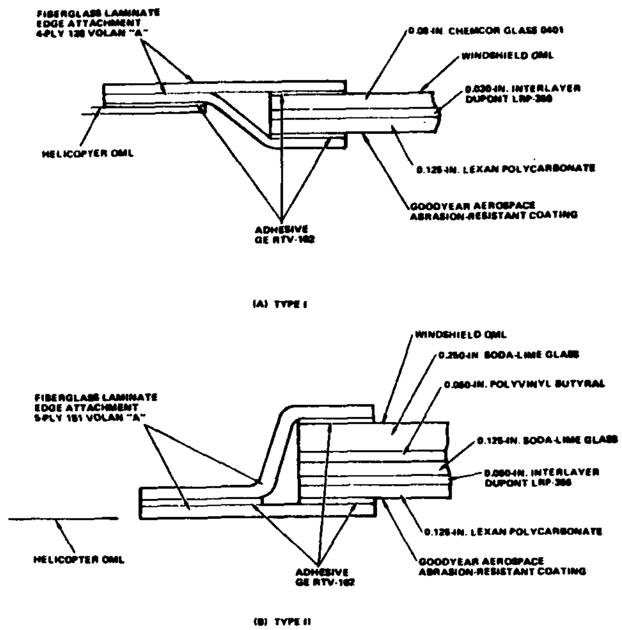

Figure 1 - Prototype UH-1 Windshield Designs

The conclusions resulting from the work performed on this contract were as follows:

1) The LRP-366 interlayer has good optical clarity and is well within all requirements (light transmission and haze) required for glass/plastic composites.

2) The adhesive bond achieved with glass and polycarbonate seems to be adequate to withstand repeated thermal cycling.

3) Based on the limited prototype work performed, it is believed UH-1 windshields of glass/plastic constructions can be fabricated successfully if:

a. The sheet interlayer can be obtained in extruded sheets of uniform thickness.

b. The flow characteristics of the interlayer can be improved either by altering the resin formulation or by developing a temperature-pressure cycle more compatible with the interlayer.

4) Constructions utilizing Chemcor glass (Type I) exhibit a greater tendency to crack during lamination because of the difficulty of obtaining the good contour match between the various plies of the composite.

BENEFITS

There are a number of benefits from this project. One of the most important is cost reduction. A rough estimate is that replacing cast-in-place adhesives with film adhesives reduces costs of transparent laminated systems by 80%.

Other benefits include longer, useful life of the windshield, greater ballistic protection, and lower weight of adhesive.

IMPLEMENTATION

A process description and manufacturing specifications have been prepared and included in the Technical Report on this subject. Another report is being prepared which will outline the advantages, disadvantages. and recommendations for implementation.

MORE INFORMATION

Additional information may be obtained from Dr. Robert E. Sacher, AMMRC, Watertown, MA 02172, AV 955-3330 or Commercial (617) 923-3330.

Summary Report was prepared by W.R. Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 474 4371 titled, "Fabrication Techniques for Track Elastomeric Compounds" was completed by the US Army Tank-Automotive Research and Development Command in July 1977 at a cost of $218,800.

BACKGROUND

The life expectancy of the steel components of a track section has steadily increased to 4,000 or 5,000 miles, depending on the track. Concurrently, the rubber components, primarily track pads, have had no increase in the average life expectancy of 1,000 to 2,000 miles due to severe chunking and chipping. Hence, the rubber components require several times the handling which results in increased logistic, storage, and maintenance costs for each individual track.

The cause for rapid wear has been the subject of considerable attention. Factors considered have been the mechanical design of the track, the composition of the rubber in the pads, manufacturing techniques, and the development of laboratory tests that correlate with pad wear. The basic fact is that tread wear on a vehicle still is the only criteria. Experience for off-the-road tire compounding does not correlate with pad wear.

A recent R&D project has developed some promising elastomeric compounds. Screening tests of these indicate that substantial durability improvement can be obtained.

SUMMARY

The purpose of this project is to establish manufacturing methods and techniques for the more durable recently developed elastomeric materials which will provide military track requiring significantly less maintenance than current production. The most promising blends were oil extended polymerized Styrene Butadiene Rubber (SBR), oil extended emulsion SBR and polybutadiene, and a non-oil extended emulsion SBR and polybutadiene. The T142 track pad was selected as the test sample for track trend rubber evaluation primarily on the basis that results will be applicable to most of the other types of production pads. Sample lots of T142 track pads, see Figure 1, were fabricated by Firestone and Standard Products Company using two basic recipes and one fiberglass reinforced (RICS) modification of each recipe. Track pad test sets #1 and #2 were evaluated for durability and compared to pads of approved production compounds over

ground gravel, hilly cross-country, and paved test courses at the Yuma Proving Grounds. Results indicated that the SBR polymer (Stereon 750) provided a durability improvement that was better than two of the production controls and approximately equal to the third.

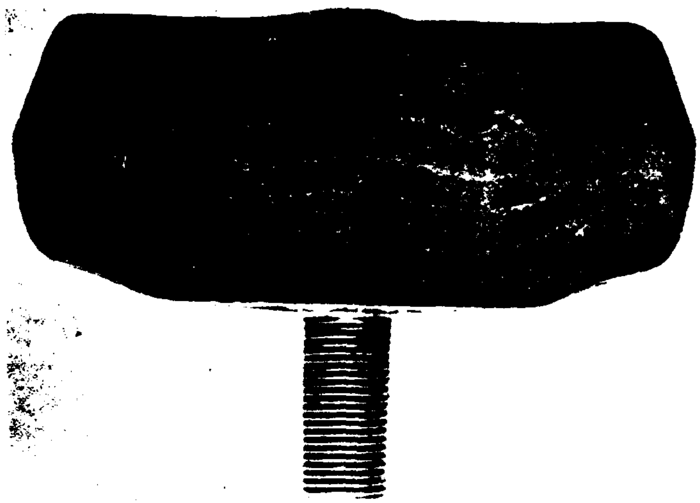

Figure 1 - Cross Section View of Vulcanized T142 Rubber Track Pad Containing Wire Cloth

Test sets #3 and #4 consisted of a total of 600 T142 pads, 300 fabricated by each contractor. The pads manufactured by Firestone consisted of compression and injection molded controls and injection and compression molded pads utilizing the polymer Stereon 750. Standard Products pads consisted of compression molded production controls, compression molded Stereon 750, and a secondary control that was compression molded. Testing of this set started the second week in December 1975 at Yuma Proving Ground. The vehicle completed 1,500 miles on the paved course and 1,000 miles on the gravel course and 400 miles on the hilly cross-country course. Results indicated a further improvement in durability could be attained by utilizing injection molding.

BENEFITS

Application of more durable track rubber will result in large savings since it is expected that a 20% to 30% improvement in durability can be attained.

IMPLEMENTATION

The results of this project are being incorporated in a major revision of track rubber specification MIL-T-11891, which includes changes other than those caused by this project. This is being updated to include Stereon 750 in a Government control recipe. The intent is that manufacturers' products will be required to perform "as good as" or "better" than this compound.

MORE INFORMATION

Additional information may be obtained from Mr. E. J. Gow, Jr. at AV 273-1331 or Commercial (313) 573-1331. A technical report No. 12091 titled, "Fabrication Techniques for Track Elastomeric Compounds" was published in September 1975 by the Mobility Systems Laboratory, TARADCOM.

Summary Report was prepared by W. R. Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 477 5019 titled, "Storage Battery, Maintenance Free (Dry-Charged, Calcium Alloy Grid, Plastic Container), Phase I" was completed by the US Army-Tank Automotive Research and Development Command in January 1979 at a cost of $139,000.

BACKGROUND

The standard military battery for vehicles is the lead-acid, antimonial grid type and has a limited storage life. The container is made of hard rubber and, not infrequently, is damaged or cracked due to demanding military requirements. It is subject to destruction by overcharge and sulfation. This causes corrosion of battery components and vehicle battery compartments. Field maintenance is required in the form of liquid level checking, addition of distilled water, checking for corrosion, cleaning terminals, and occasionally replacing terminal cables and connections. The average life for the standard batteries used by 2-1/2 ton and larger trucks and track vehicles is currently 24 months.

In recent years, low maintenance batteries using calcium alloy grids and plastic containers have been developed commercially for a wide market. They do not, however, meet military requirements. New specification MIL-B-11188 was developed recently for military low maintenance battery type applications.

SUMMARY

The purpose of this project was to apply the new commercial manufacturing methods and technologies to producing a military size 6TN battery meeting the new specification. The new battery is to be as maintenance free as possible, dry-charged, and utilizing a calcium alloy grid and plastic cover and container.

The approach taken was to use the basic element size of the current 6TN battery and adapt this for use with a plastic case and cover. The resulting battery has 23 plates pasted from conventional lead oxide mixes. The grids are molded from lead calcium alloy size 5-1/4 inches high and 4-1/4 inches wide. The separators are made of microporous polyethylene and are the envelope type which completely enclose the positive base.

Evaluation of a number of possibilities for the case and cover revealed that the optimum material in terms of both cost and performance was extra high impact polypropylene, specifically Exxon CD391. The cover designed has a manifold venting system to which two 1/4" I.D. gas relief tubes can be attached. The vents are centered on the sides that are without handles. A combination arrestor and water barrier is incorporated in the venting system, internally, at the area of the outer venting aperture. This is accomplished by sandwiching a layer of microporous polypropylene film between two layers of porous polypropylene sheet into a single unit.

The battery is provided with a combination indicator as a part of one of the filler plugs. It is waterproof and flush with the top of the battery except that the top of the indicator rod is slightly depressed so that the plug will still be removable with a screwdriver. Instructions for its use are provided on a label attached to the battery. When the indicator is dark with a green dot showing, the battery charge and electrolyte level are sufficient. If the indicator is dark with no green dot showing, the fluid level is sufficient, but the battery charge is low and the battery should be recharged. If the indicator is light, the electrolyte level is low and water should be added. The state of charge is unknown.

Dry charging of the calcium plates was accomplished, at least partially. Problems were encountered both in production and in activation performance. However, it is felt that improved production techniques can be evolved.

In all, 143 batteries like that shown in Figure 1, have been manufactured and delivered to the Government.

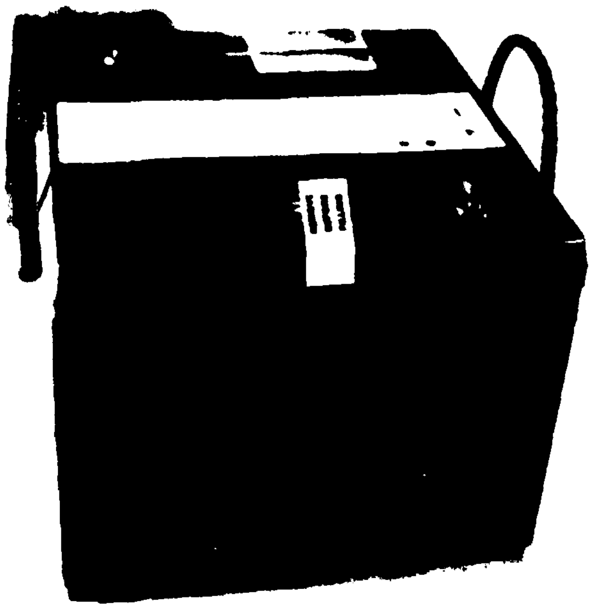

Figure 1 - Prototype Calcium Alloy Grid, Dry Charged, Low Maintenance GTN Battery

BENEFITS

The adoption of the calcium alloy grid plates is expected to provide up to three times the "wet" storage life of batteries in use today. The inherent capability of the calcium alloy grid battery plates should also virtually eliminate battery failures due to overcharge.

The new battery is housed in a high-impact plastic container to reduce battery breakage in the field. It is believed that this will eliminate most leakage and sealing problems.

The average life for batteries used by 2-1/2 ton and larger trucks is currently about two years. It is hoped that at least three years average life will be obtained with the new calcium alloy battery.

IMPLEMENTATION

This project was finished with the delivery of the prototype batteries to the Government. However, there is a follow-on Phase II project which has just begun. For the most part, it consists of detailed laboratory performance evaluation and field testing of the batteries at TECOM.

MORE INFORMATION

Additional information may be obtained from Joseph H. Reinman, TARADCOM, AV 273-2492 or Commercial (313) 573-2492.

Summary Report was prepared by W.R. Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECH

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 474 5052 and 475 50?2 titled, "Army Engineering Design Handbook for Production Support" were completed by the US Army Management Engineering Training Activity in February 1980 at a cost of $329,541 and $296,766, respectively.

BACKGROUND

There was a need for latest scientific and technical knowledge for the many scientific disciplines of interest to the Army. There were no related efforts undertaken in the Government or Private Industry to provide such information. This effort was undertaken to provide "Engineering Design (ED) Handbooks" which would collect, tabulate, and provide guidance and techniques in up-to-date scientific and technical knowledge for the design, development, production, and engineering of Army hardware.

SUMMARY

The objective of this effort was to provide the latest technical scientific, and engineering data to support the production and procurement of military hardware, software, and equipment. This effort consisted of the initiation, revision, and updating of technical, scientific, and engineering data. This effort was accomplished through a contract to develop and improve ED handbooks. The handbooks developed or modified with FY74 and FY75 funds were titled, "Servomechanisms," "Dynamics of Ballistic Impact," "Gun Tubes," "Vulnerability of Guided Missile Systems to Electronic Warfare," and "Army Weapon Systems Analysis."

Project accomplishments for this effort were too numerous to include discussions of each in this report. One example selected here to demonstrate typical accomplishments was the "Army Weapon System Analysis, Part Two." This handbook covers some of the more advanced topics in the field of weapon systems analysis; including measures of effectiveness, target detection phenomena and probabilities, combat theory for homogeneous and hetergeneous forces, weapon equivalence studies, optimal weapon firing policies, weapon-target allocation problems, human factors and human engineering, analysis of costs, cost-effectiveness studies, survivability considerations, countermeasures and their analytical treatment, war games, computerized combat simulations, example evaluations of small arms, tank and anti-tank weapons, field artillery and air defense weapons, and cost and operational effectiveness analyses.

BENEFITS

The benefits derived from the Engineering Design Handbook effort are the collection, tabulation, and provision of consistent guidance and techniques in up-to-date scientific and technical knowledge that can be used in the design, development, production, and engineering of Army hardware across the board.

IMPLEMENTATION

The Engineering Design Handbooks AMCP 706-136 titled, "Servomechanisms" and DARCOMP-P 706-417 titled, "Vulnerability of Guided Missile Systems to Electronic Warfare" were completed along with the updating of five other ED Handbooks:

DARCOM-P 706-101	Army Weapon Systems Analysis, Part 1
DARCOM-P 706-102	Army Weapon Systems Analysis, Part 2
DARCOM-P 706-158	Dynamics of Ballistic Impact, Part 1
DARCOM-P 706-159(S)	Dynamics of Ballistic Impact, Part 2
AMCP 706-252	Gun Tubes

These books provide ED information to Army and other DOD requestors with a "Need to Know." Copies of these handbooks may be obtained from Letterkenny Army Depot or the Defense Technical Information Center.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. P.W. Wagner, AMETA, AV 793-6735 or Commercial (309) 794-6735.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 574 1261 titled, "Provision of Prototype Equipment for Determination of Level in White Phosphorus Storage Tanks" was completed by the US Army Armament R&D Command in July 1976 at a cost of $40,000.

BACKGROUND

A new type of system was required to measure the level of white phosphorus in underground tanks at Pine Bluff Arsenal (PBA). Another new type of system was also needed to measure the amount of white phosphorus being pumped from railroad tank cars to underground storage tanks. The only method available to measure the amount of white phosphorus in storage was relatively inaccurate. The level of white phosphorus in the underground tanks was checked by a dipstick method. The dipstick method was accurate only to within two or three inches which allowed for an error of up to 12,000 pounds in the estimated weight of white phosphorus.

SUMMARY

Two prototype systems were developed to solve the white phosphorus measuring problems. A prototype system was developed to measure the level of white phosphorus in a pressurized tank. This device was capable of operating up to 160°C and withstand the solidfying of white phosphorus (WP) at 105°C.

A float was devised that floats at the interface between the water and white phosphorus in the tank, see Figure 1. The float is confined to vertical motion on a hollow rod that extends from the top to the bottom of the tank. Inside the rod is a magnet that follows magnets imbedded in the float. The level of the float can then be determined by an electrical instrument attached to the follower magnet. The amount of white phosphorus in the tank can then be determined to within a few hundred pounds.

An ultrasonic flowmeter was developed that could be clamped on the transfer pipe through which molten white phosphorus was pumped into the storage tank from railroad cars. An ultrasonic transmitter was placed between two ultrasonic receivers on the pipe. When there was flow, the transmitted signal reached the downstream receiver before it reached the one upstream. The time difference in signal reception between the two receivers was proportional to the flow rate. Circuitry then translated the time difference into an electric meter display which showed both the flow rate and total flow. A density meter automatically cuts off the total flow meter when water is detected; water is used to displace the molten WP from the rail-road cars.

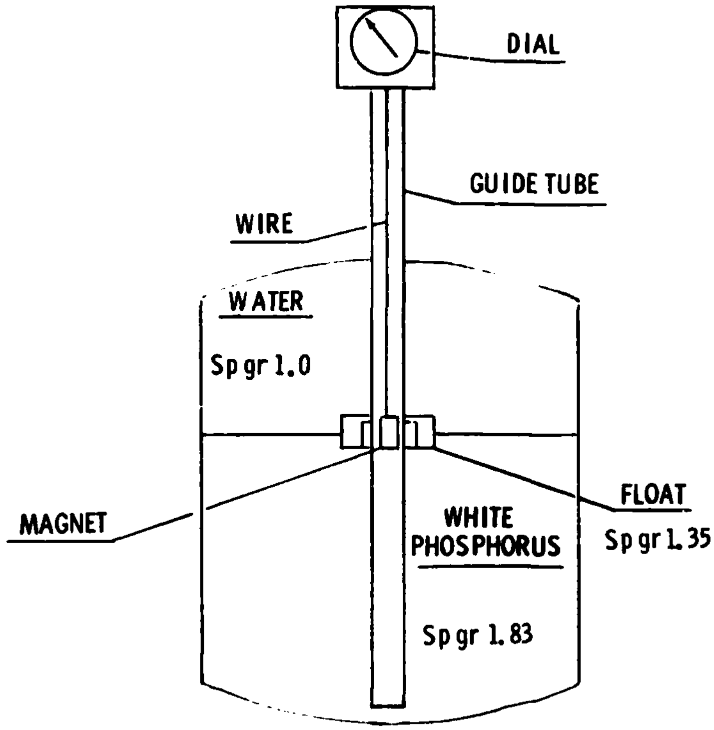

Figure 1 - Level Gauging System for Under-Ground Storage Tanks

BENEFITS

Flow rate of the white phosphorus can now be measured much more accurately. The amount of white phosphorus in the underground tanks will be known to a greater degree of accuracy (±1500 lb). The level gauging system is adaptable to both above ground and underground tanks. The level gauge can output either a pneumatic or electrical signal for a continuous reading.

IMPLEMENTATION

The flow meter is being used in white phosphorus transfer operations at PBA. The level gauge has been installed in an underground white phosphorus storage tank at PBA and has not required any maintenance after three years of continuous operations.

MORE INFORMATION

Additional information on this project is available from Mr. B.J. Miller, AV 966-2612 or Commercial (501) 534-2612 at Pine Bluff Arsenal.

Summary Report was prepared by Steve Albrecht, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 575 3062 titled, "Pellet Thermal Power Supply Technology" was completed by the US Army Armament Material Readiness Command in September 1978 at a cost of $150,000.

BACKGROUND

Although thermal batteries were developed for fuzes in non- or low-spin ammunition such as bombs, rockets, and mortars, they were not suitable for artillery fuzes. For high spin systems such as projectiles and spin mortars, it has been necessary to use lead oxide liquid reserve power supplies. Recent technology has progressed to the point where it may be possible to apply thermal batteries there as well. Pellet thermal batteries offer the virtues of ruggedness, low internal resistance, less voltage dependence on environmental temperature, and a high degree of storage stability, i.e., 20 years.

SUMMARY

The purpose of this project was to establish a manufacturing technology posture for pellet-type thermal batteries. In the past, manufacture of such batteries has been on a low volume basis. A considerable amount of tailoring of small batches of materials and components was necessary to obtain batches of batteries that met specifications. This approach precluded the attainment of low cost devices.

A contract was awarded to Catalyst Research Corp (CRC) to develop manufacturing processes, techniques, and equipment for volume production of pellet type thermal batteries. It was to be capable of accommodating an annual battery production rate of 100,000 to 500,000 per year at the lowest possible cost.

Due to space constraints, a design utilizing a 12-cell stack, and a high density pellet was settled upon. It showed the most promise of giving reproducible performance in the 40-second active life bracket. A copy of the design of the component arrangement of the test vehicle battery is shown in Figure 1. It is roughly 1-1/4" high by 1-1/4" in diameter.

Full scale manufacturing batches of materials were prepared and a substantial number of batteries were made. Physical and chemical analysis of the material batches coupled with battery testing was then carried out with the intention of assessing manufacturing reproducibility.

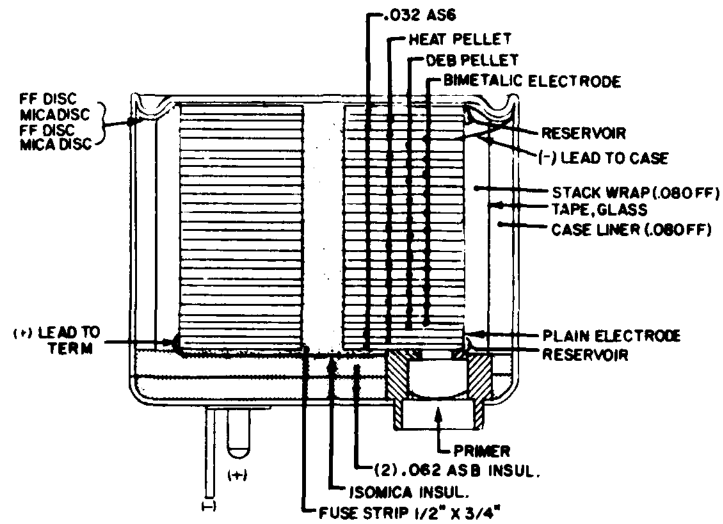

Figure 1 - Prototype Thermal Battery for Rocket Power Supply

The results of the testing showed several interesting results. First of all, separately processed batches of materials displayed insignificant differences in chemical composition and particle size distribution. Secondly, battery performance was closely grouped when the specifications were fairly reasonable. This would appear that the battery developed is suitable for low spin applications such as the 2.75 inch rocket power supply. However, the third result showed that extreme performance of the batteries, i.e., total operating life and response to high spin or extraordinarily high temperatures, displayed considerable spread with no clear correlation to variation in processing or fabricating parameters. This would appear to preclude use of this battery in artillery fuzes.

It was apparent that the industry must still rely on the building of batteries to evaluate the acceptability or uniformity of materials that will be fabricated into pellets.

BENEFITS

The expected benefits of this project to the Government are greater reliability and reduced cost for thermal batteries in non- or low-spin ammunition. Most of the benefits will be deferred, however, until the second year follow-on effort is completed.

IMPLEMENTATION

For practical purposes, this also will be delayed until the second year follow-on effort is completed. It is intended in the second year to analyze the basic raw materials in terms of the pellets produced. The goal is to have the manufacturer know that suitable batches of materials will produce suitable batches of batteries under extremes of performance stress. This should widen the potential implementation of this work.

MORE INFORMATION

Additional information may be obtained from Mr. A.A. Benderly or Dr. J.T. Nelson at AV 290-3114 or Commercial (202) 394-3114.

Summary Report was prepared by W.R. Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 573 4069 and 574 4069 titled, "Modernization of Mortar Body Depalletization and Carton Opening" were completed by the US Army Armament Research and Development Command in February 1978 at a total cost of $454,000.

BACKGROUND

Studies indicated that predominately manual operations were utilized to depalletize, open, and unpack cartons to feed the melt-pour operations. At times of high demand, such as mobilization, the required manpower may not be available. A need existed to provide an efficient, automated line with a high degree of reliability and a minimum dependancy upon manpower. Most of the individual equipment required was available commercially but a total system had to be developed.

SUMMARY

The purpose of this project was to develop and install the equipment necessary to accept pallets of packaged metal mortar projectile parts and introduce them to the melt-pour conveyor with a minimum of operator attention. The present equipment was developed for the 81mm, M374A3 and the 60mm, M720 projectiles.

A description of the equipment operation is as follows: A fork lift places a pallet of cartons on the input conveyor. The operator then removes the pallet straps and activates a signal to indicate that the loaded pallet is ready. When the succeeding station is empty the pallet is automatically advanced and a strap detector insures that only pallets without straps will be indexed. Up to three pallets can be loaded on the infeed conveyor.

The pallets are moved to the separation conveyor and the layers are separated into rows for depositing on the unscrambling conveyor where they are singulated and oriented for the slitters. The carton is passed thru two sets of slitters, each of which cuts two sides.

The cut carton is positioned against the lid remover, the lid is removed, and the load is pushed off of the bottom lid onto an adjacent carton. The carton and divider are lifted from the shells and the shells are moved one row at a time onto the output conveyor. The output conveyor singulates the shells and feeds them to the melt-pour line. The empty cartons are conveyed to a baler. A control system at the output end of

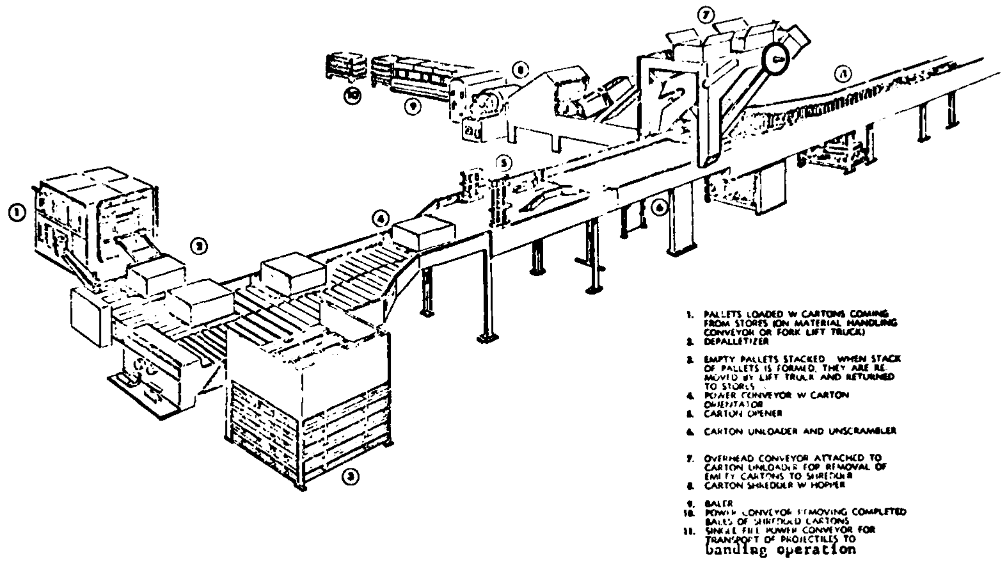

Figure 1 - Automated Depalletizer, Carton Opener, and Projectile Unloader

the system will sequentially shut down the various operating elements whenever the output of the system exceeds the rate at which parts are removed from the system.

BENEFITS

This project provided an automated depalletization and carton opening system for 60mm and 81mm mortar ammunition that can be used to alleviate manpower shortages during MOB production.

IMPLEMENTATION

The equipment has been installed at KAAP and is available if production resumes.

MORE INFORMATION

Additional information concerning this project may be obtained from Mr. Laurence Weiner, US Army Armament Research and Development Command at AV 880-6506 or Commercial (201) 328-6506.

Summary Report was prepared by Hal Weidner, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 574 4278 titled, "Bulk Handling of Hexamine" was completed in November 1976 by the US Army Armament Research and Development Command at a cost of $40,000.

BACKGROUND

A modernization program was planned and approved at Holston Army Ammunition Plant (HAAP) to construct a Central Hexamine/Acetic Acid Mixing Facility to replace three separate mixing facilities. Presently, hexamine is packaged in 50 pound three-ply bags. The individual bags are palletized at the supplier's plant at 3,000 pounds per pallet and shipped to HAAP. The pallets are unloaded at HAAP and placed in temporary storage. When required, the bags are removed from temporary storage, opened, and the hexamine charged into processing equipment. If a method for handling hexamine in bulk form could be established, considerable cost savings could be realized. This savings would be in the form of less cost of raw materials since the vendors would save time and materials by packing the hexamine in large bins instead of the 50 pound bags.

SUMMARY

The purpose of this project was to establish a method for handling hexamine in metal bins and to design a system to receive hexamine in bulk. Initial testing of bulk quantities indicated caking problems with hexamine. Therefore, the system was designed for bag handling with the capability to add bulk handling at a future date. Bulk handling was still considered feasible, but more testing was required.

Two approaches to solve the caking problem were studied. One was to investigate mechanical means for pulverizing the caked hexamine, the other to study the addition of chemicals to the hexamine to reduce caking tendencies.

In order to evaluate mechanical methods, the feasibility of using a Tumbler-Blender to break the caked hexamine into six inch diameter lumps was studied. A picture of the Tumbler-Blender is shown in Figure 1. To test the Tumbler-Blender, aluminum tote bins were filled with hexamine and stored for three to seven weeks. All hexamine had hardened in the bins regardless of the storage time. The bins were then tumbled in an attempt to break up the hexamine. The hexamine did not break up completely and a lump about two feet in diameter remained after discharging

the loosened hexamine. To facilitate breaking the hexamine lumps, several of the bins were modified with internal projections. The hexamine from the previous tests had to be broken out of their storage containers and placed into the modified bins. After allowing three weeks for the hexamine to harden in the modified bins, tumbling tests were conducted. The results were only partially successful as several large lumps of hexamine remained. The tests were considered unreliable because of the age of the hexamine and the reworking of the hexamine made it nonrepresentative of actual conditions.

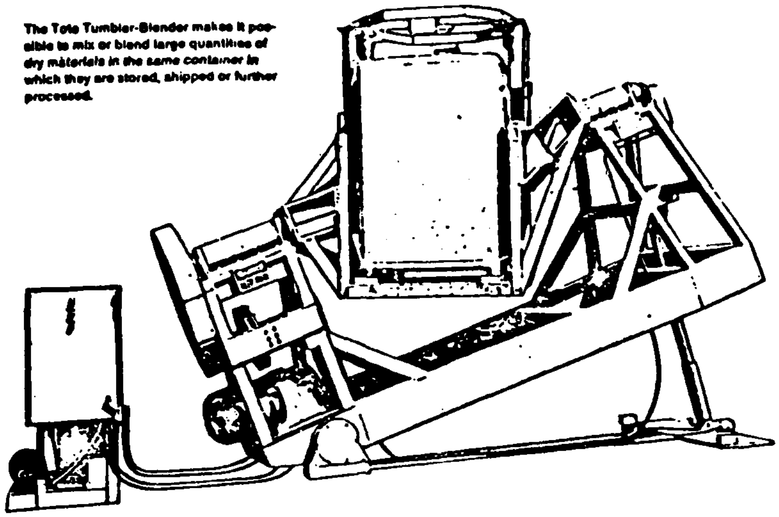

Figure 1 - Tumbler-Blender

Based on the testing of aluminum tote bins, the Tumbler-Blender did not provide sufficient pulverizing of the caked hexamine. The addition of internal projections in the tote bins did not improve the pulverizing of the caked hexamine.

Several anti-caking agents for hexamine were evaluated in the laboratory. A flow test was used for testing the anti-caking properties of the test materials. The test was performed by tilting a transparent vial containing hexamine coated with the agent under evaluation from the vertical until the hexamine was noted to flow. The amount of tilt required to cause the hexamine to flow was measured in degrees from the upright position.

The effect of the anti-caking agent on nitrolysis and the resulting product was determined by performing a hexamine nitrolysis in standard laboratory equipment with the hexamine coated with three percent of the agent under test. Based on laboratory testing of anti-caking agents, the following conclusions were drawn:

a) Magnesium carbonate was not ideal as an anti-caking agent because the hexamine coated with $MgCO_3$ crusted during a nine month storage period at an ambient temperature of 15.6 - 21.1°C. The hexamine coated with magnesium carbonate nitrated normally and the products (HMX and RDX) did not show any increase in impact sensitivity tests.

b) FLO GARD and Silene EF were excellent anti-caking agents for the hexamine. However, they contributed to the sensitivity of the nitrated product (RDX and HMX) when the hexamine, used in the nitrolysis, was coated with three percent of the above anti-caking agents. Because of the increased sensitivity induced by these agents, the FLO GARD and Silene EF were considered not suitable for use as anti-caking agents for hexamine.

Based on the results of this effort, the decision was made to terminate the project and return the remaining funds for use in other projects.

BENEFITS

Methods for receiving and handling hexamine in bulk quantities was not achieved and therefore no benefits were realized.

IMPLEMENTATION

Since the objectives of the project were not met, there was no implementation.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. S. Dollman, AV 880-3717 or Commercial (201) 328-3717.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 576 4300 titled, "Product Assurance in Support of Plant Modernization" was completed by the US Army Armament Research and Development Command in December 1978 at a cost of $353,000.

BACKGROUND

Current modernization and production base projects are involved in the development of automated production equipment. All of these projects contain, in part, product assurance efforts and the development of inspection equipment. In addition, the current programs handle the product assurance requirements separately and independently. As a result, there will be proliferation of solutions resulting in higher capital investments and additional training and maintenance costs. This project was undertaken to eliminate these problems. Successful completion of this effort would develop standardized product assurance methods and techniques (including testing and test equipment) that would be compatible for each separate and distinctively different modernized automated production facility. An increase in productivity should result by reducing assembly defects through control of operations with state-of-the-art inspections and instantaneous feedback for timely and effective corrective action as needed.

SUMMARY

The objective of this project was to insure that Reliability, Availability, and Maintainability (RAM) are treated as design parameters of equal importance with other technical and functional parameters early in the design process of modernization. An additional objective was to assure that timely, accurate, and independent evaluations of designs, equipment, and systems are performed and documented to permit effective technical and managerial decision making and corrective action. This project approach included sending out questionnaires (56 total) on each P-15 Modernization and Expansion project initiated in the FY70-73 time frame. The returned questionnaires were reviewed to obtain a status report of the projects describing the extent and success of Quality Assurance efforts in support of Plant Modernization Facility Projects. Additionally, on site visits were made by ARRADCOM personnel to review prove-out testings at modernized facilities in order to gather information pursuant to this project.

A PBM Product Assurance Master Plan was prepared and staffed as a result of this project. Figure 1 shows the product assurance management control system and illustrates the interrelationships of the activities involved in the procurement, evaluation, and acceptance of Modernization and Expansion projects.

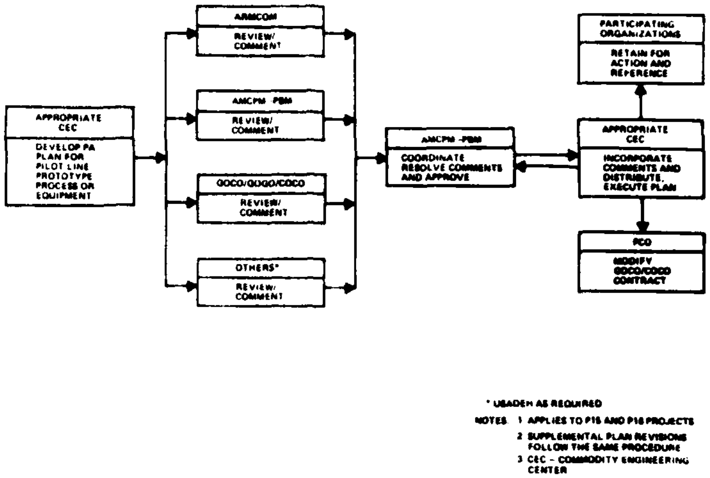

Figure 1 - Product Assurance Plan Modernization and Expansion Projects

BENEFITS

This project resulted in the establishment of a formal Product Assurance Plan under the aegis of PM-PBM which was compatible with the overall production Modernization and Expansion or MMT system.

IMPLEMENTATION

The results of this project were adopted as PBM Pamphlets titled, "Product Assurance Master Plan," DRCPM-PBM Plan 702-1, and "Prove-Out Plan," DRCPM-PBM Plan 702.2. This project has laid the foundation for ARRADCOM product assurance support to the Modernization and Expansion facility projects initiated since 1978.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. F.J. Fitzsimmons, ARRADCOM, AV 880-6534 or Commercial (201) 328-3906.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 673 6784 titled, "Engineering Study and Materials Evaluation for Obturator Pads" was completed in January 1975 by the US Army Armament Command at a cost of $75,000.

BACKGROUND

Obturation with cased ammunition, as used in small arms and the smaller cannon, is effected by expansion of the cartridge case by the propellant gas pressure. With bag-loaded ammunition, however, there is no inherent obturation and it must be provided for by a separate seal in the breech mechanism. In US cannons, this is accomplished by an elastomer pad. The metal anterior portion of the breech block assembly is forced back by the pressure of the propellant gases thereby producing a force on the obturator pad which is transmitted radially through the seal rings to the tube seat, thereby sealing the breech.

It is important that obturator pads seal satisfactorily over a wide range of ambient temperatures. The problem is with very low temperatures. Under these conditions, the elastomeric pad materials become stiff and fail to transmit pressure as they must for effective obturation. Also, elastomers have a coefficient of thermal expansion almost ten times that of steel. Hence, as the temperature falls, the pad shrinks much more than does the cavity in the breech assembly.

SUMMARY

The objective of this project is the development of an obturator pad for bag-loaded cannons which will effectively seal the breech through the entire temperature range of $-50^{o}F$ to $145^{o}F$. This will result in lower costs and simplified logistics.

Methods were developed for evaluating the important characteristics of candidate obturator pad materials simply and inexpensively in the shop. The three principal ways that an obturator pad can fail as a seal are: flexibility, speed of response, and thermal dimensional stability.

The important measure developed to measure flexibility at different temperatures is the "A" ratio. This is the ratio of radial pressure to applied axial pressure.

The "A" ratio is normally and easiest measured as an equilibrium value. However, the pad material property actually of importance is the dynamic value. The pad must transmit the required sealing pressure in a few milliseconds. Testing revealed that there is an effect of material and temperature on the speed of response of obturator pad materials. Fortunately, however, the delay is not large for any of the candidate materials tested. All are acceptable in this regard and the "A" ratio can be measured as an equilibrium value.

Because of the much greater (10X) coefficient of thermal expansion, the obturator pad shrinks much more than does its cavity in the breech assembly as the temperature falls. As it shrinks, the pad fails to seal properly. The important value is the diametral shrinkage. Because of the design of the breech mechanism, rather large axial dimensional changes can be accommodated but this is not true of diametral dimensional changes.

Of all the candidate materials tested, the most promising elastomer was the castable polyurethane made from Adiprene L-42 as shown in Figure 1. This elastomer retains excellent flexibility to temperatures below -65°F. Anisotropic pads could also be made from this elastomer by incorporating 1/4 inch glass fibers in the formulation. In this way, the pad was constrained from changing dimensions in the important diametral direction.

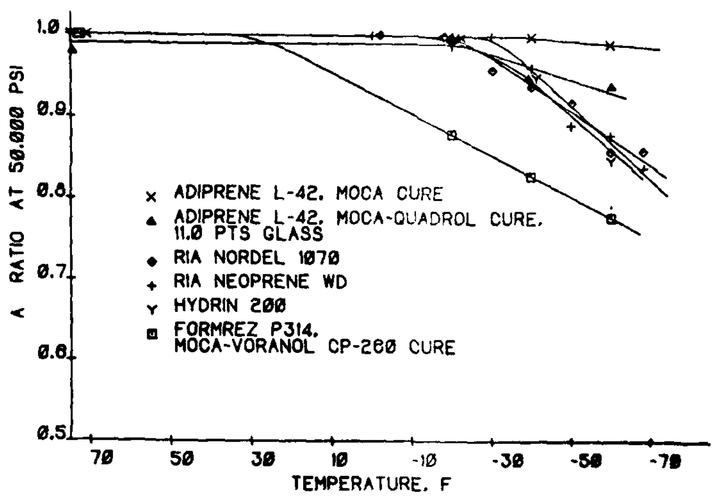

Figure 1 - Superior "A" Ratios of Adiprene L-42 Blends

BENEFITS

A single pad which will function at all ambient temperatues will result in lower costs and simplified logistics. Potential savings were orignally estimated at $70-$88/weapon.

IMPLEMENTATION

This project has not been implemented because a firm requirement for these new type obturator pads has not yet been established.

MORE INFORMATION

Additional information may be obtained from Dr. R.S. Montgomery, AV 974-4178 or Commercial (518) 266-4178. A final report titled, "Broad Temperature Range Obturator Pad Materials" was published in January 1975 by the Benet Weapons Laboratory, Watervliet Arsenal, Watervliet, NY 12189, Technical Report WVT-TR-75005.

Summary Report was prepared by W.R. Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 673 7123 titled, "Advanced Plastic Welding Technology for Fabrication of Weapons Support Accessories" was completed by the US Army Armament Command on November 30, 1975 at a cost of $33,700.

BACKGROUND

Current plastic welding technology is limited by a number of factors. These include: equipment restrictions such as fixed sealing profiles and dimensions, inability to weld certain classes of plastics, parts modifications required to obtain welds, machine control variations that create non-uniform welds, and high operational costs. It is believed that advanced welding techniques will be about 50% less costly than currently used fastening methods. The savings could result from the elimination of adhesives or metal fasteners and the reduction of assembly time as well as replacement of metal parts with plastic.

Earlier work looked broadly into six plastic welding processes and a wide variety of thermoplastic materials. Not one of these methods was found to be best for every application. Each had its own advantages and limitations which were dependent on the specific application and the plastic to be welded.

SUMMARY

For this effort, ultrasonic welding was selected as the main process to evaluate. Hughes US Army 30mm Lockless Cartridge Cases fabricated from five different thermoplastics were obtained. The five plastics were polystyrene, polyethylene, polypropylene, nylon, and ABS. The cases were machined to give a joint design suitable for ultrasonic welding, since they were originally designed for joining with adhesives.

An ultrasonic welder with sufficient capacity for welding parts of this size (700 watts) was obtained. The cases were then welded using different welding parameters (varying weld time, hold time, and weld pressure) with the object being to obtain cases that were "hermetically" sealed.

The polyethylene and polypropylene cases proved to be virtually non-weldable. The nylon cases gave very spotty welds with short areas along the weld line joined and long areas where no welding took place. The ABS and polystyrene cases did give fairly high strength welds in some cases, but did not provide hermetic seals. In addition, in order to get the best welds, it was necessary to increase the weld time and pressure to the point where there was excessive flash in the weld line.

A contributing factor to the poor welds obtained was the selection of the auxilliary equipment, i.e., the horn. Horns are usually designed for the piece to be welded. The horn used for this project was an "off-the-shelf" model.

BENEFITS

This particular application did not prove successful primarily due to the distance of the weld joint from the welding horn. Nevertheless, the work conducted showed that ultrasonic plastic welding, when performed using compatible equipment and material designed for a specific operation, offers improved cost savings and corrosion resistance over the existing use of fasteners or adhesives. Any thermoplastic weapon components which require joining to similar plastic parts will benefit if they can be joined by welding rather than by methods currently employed, which normally involve the use of fasteners or adhesives.

IMPLEMENTATION

The final technical report titled, "Plastic Welding for Fabrication of Weapons Support Accessories" provides the necessary information to permit the welding of plastic components.

MORE INFORMATION

Additional information may be obtained from Mr. W.F. Garland, ARRCOM, AV 793-5039 or Commercial (309) 794-5039.

Summary Report was prepared by W.R. Hierseman, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 673 7261 titled, "The Improvement of Processes Involved in Plastic Replica Component Manufacturing" was completed by the US Army Armament Research and Development Command in April 1975 at a cost of $79,718.

BACKGROUND

Currently the optics used in fire control systems are composed of glass. Earlier efforts by both government and industry have attempted to produce high quality optical elements from thick epoxy resin castings. However, because of the imperfect dimensional stability of even the best plastics, thick castings have failed to produce high accuracy elements. Later efforts attacked the instability problem of plastics by reducing the thickness of the plastic layer and obtaining rigidity by means of stable preformed backing structure. Problems were encountered with cracking of glass masters, plastic voids, cosmetic surface defects and difficulty in separating elements after casting. This study initiated efforts to improve the latest plastic casting process for the manufacture of mirrors, hollow corner prisms, and other elements used in fire control optics.

SUMMARY

This project was directed towards the improvement of the replicating process (a thin film molded cast epoxy reproduction of an optical surface), determination of the process limitations, establishing the design criteria for fixtures/components and development of an economic guide.

The approach was to fabricate the tools and fixtures necessary to produce mirrors based on the methods previously developed. Process parameters which were necessary to obtain mirrors of a quality equal to those made from glass were determined and mirrors were produced.

The basic process involved the reproduction of a polished mirror surface, in the form of a thin film epoxy casting complete in all details, on an aluminum preform. The double replication process used in this study is a two stage process shown in Figure 1. Starting at the upper left, the pyrex master which contains the precise optical surface to be replicated was vacuum coated with copper. Then, the stainless steel submaster (upper section of fixture) was used to prepare the Epon (Epoxy resin and hardner) cast layup. This first replica was then vacuum coated with copper. The submaster was then installed in the layup fixture containing the preforms

made of aluminum. A second Epon casting was then made on the preform. This preform was then vacuum coated with chromium, silicone monoxide, aluminum and silicone monoxide respectively. This second replica became the mirror.

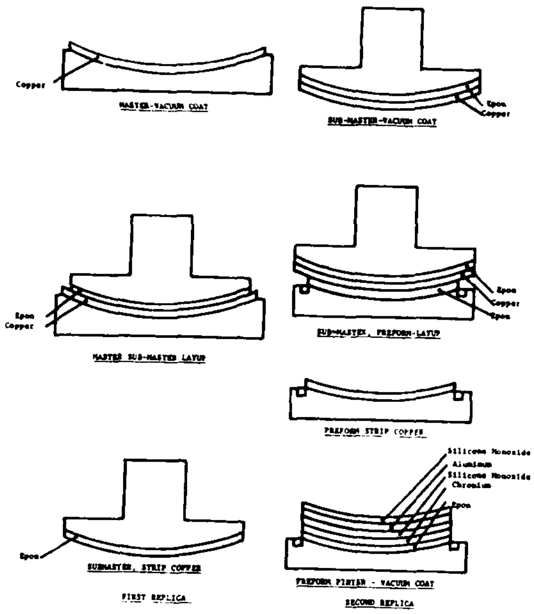

Figure 1 - Double Replication Process

Attempts to produce the first replicas with the fixtures were unsuccessful. The master cracked during the post cure cycle, the layup parted easily, and there were plastic voids in the replica and air bubbles in the cast epoxy.

The layup fixture was modified by providing hardened adjustable pins that could be locked with set screws and locking screws to hold the fixture together during the curing cycle. It was determined that the master cracking was caused by thermal shock and internal stress. To solve this problem, the masters were made of Cer-vit (ceramic glass product of Owen-Illinois) with backup masters of 17-4PH stainless steel. In addition, a study was made to minimize the epoxy deflects by varying the proportions of epoxy resin to hardner. It was found that a mixture of 100 parts epoxy to 15 parts of hardner by weight produced a plastic with no visible defects. Various materials such as silver, aluminum and copper were tried as release coatings for the application process. The best results were obtained with barely opague coatings of copper.

Since one of the primary purposes of this effort was to replicate parabolic surfaces into spherical surfaces, the condition of a thickness gradient was simulated by using submasters and preforms whose radii differed from that of the master by as much as .015 inches. It was found that a thickness of less than .002 inches permitted the defects of the form to telescope through and a thickness of .012 inches or more caused measurable distortion. Plastic thickness limits were set at a minimum of .003 inches and a maximum of .010 inches.

A pilot production run was then made incorporating all of the changes and modifications recommended by the studies. Results indicated that the quality of the replica mirrors made from the stainless steel masters were equal to those made from glass masters.

The process will not, at the present state-of-the-art, provide mirrors of the same high optical quality as precision glass mirrors. However, it will provide a relatively simple method for reproducing hard to machine surfaces with nominally good reflective surfaces. These surfaces averaged 89 percent reflectivity using stainless steel masters, and 91 percent reflectivity using Cer-vit.

BENEFITS

This project provided an improved procedure for manufacturing spherical and aspherical mirrors by the double replication process using thin film cast epoxy resins as the replica. Use of these techniques would result in lower production costs, reduced otical grinding/polishing equipment and reduced number of optical technicians required.

IMPLEMENTATION

A product standard practice description was prepared for the double replication process for mirrors and was disseminated to other government agencies and to private industry.

MORE INFORMATION

To obtain additional information, contact the project officer, Mr. N Scott, AV 880-6430 or Commercial (201) 328-6430.

Summary Report was prepared by Pete Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 675 7419 titled, "Low Cost Reciprocating Screw Molding of Thermosetting Plastic Weapons Components" was completed in April 1979 by the US Army Armament Command at a cost of $45,000.

BACKGROUND

Until recently, thermosetting plastic weapons components could not be economically produced by the molding techniques available (transfer and compression). The recently developed reciprocating screw injection machine has the possibility of producing low-cost functional thermosetting plastic weapons components. Manufacturing procedures for the fabrication of thermosetting components utilizing injection molding were investigated under this project which is a follow-on to 674 7419.

SUMMARY

Two types of injection molding systems were explored - warm manifold and hot runner. The advantages of warm manifold molding are that there are fewer problems with small parts and less material is wasted. Hot runner molding suffers from excessive manifold freeze up which is a major deterrent to its successful use in industry. However, hot runner mold would cost 50% less and take one-tenth the time to debug than a warm manifold mold. It was decided to continue with the hot runner system because the warm manifold system temperature is not adequately controlled at the manifold/cavity interface.

A hot runner injection mold was fabricated for the M16 handguard. The M16 handguard mold cavities were machined by electrical discharge. Several transparent polystyrene handguards were molded to allow the use of a polariscope. A polariscope was used to find process induced stress concentrations and to determine in-cavity plastic flow patterns. Results of the analysis were used to optimize the runner system and mold venting system to reduce stress.

Several modification were made to the mold. Runners and gates were enlarged to enhance plastic flow. Vents were cut into the cavities to exhaust gases. An air cooling system was designed for the sprue bushing to prevent nozzle freeze-up. After these mold modifications, the thermosetting plastic items were successfully molded. Fifty sets of handguards have been submitted for field testing.

BENEFITS

A major benefit resulting from this project will be more durable handguards for the M16 rifle. This project also provides the Army with a capability to produce high quality thermoset plastic weapons components with significantly improved service life over that of compression molded end items. A 30% cost savings over compression molding is anticipated because of elimination of manual operations of compression molding.

IMPLEMENTATION

The reciprocating screw thermosetting plastic molding machine and a mold for the M16 rifle handguard are now available for production purposes at the Rock Island Arsenal, Illinois.

MORE INFORMATION

Additional information on this project is available from Mr. Wilber Veroeven, AV 793-3266 or Commercial (309) 794-3266.

Summary Report was prepared by Steve Albrecht, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 773 3509, 774 3509, and 775 3509 titled, "Production Technology for Self-Luminous Light Sources" were completed by the US Army Mobility Equipment Command in December 1974 at a total cost of $495,000.

BACKGROUND

Private industry has done a considerable amount of work in the manufacture of phosphors for cathode ray tube application where the phosphor is activated by an electron beam. Very little work has been done by industry on self-luminous sources of the type required by the military for fire control instruments, vehicle instrument panels, and various types of markers lighted by external power sources. Because the market for these types of sources were limited to military applications, these projects were funded by the Army to establish an efficient process for their manufacture.

An FY72 project provided the design criteria for production techniques and completed plans for a pilot production line.

SUMMARY

The objective of these follow-on projects was to provide an automated production technique for minature self-luminous lights and a method of producing uniform phospor materials for radioluminescent use. The FY73 funds established the pilot production line with automated techniques. The FY74 funds provided for testing of the production capability. The FY75 funds provided for the optimization of production techniques and the progressive development of quality control procedures to assure efficient utilization of the established process.

Principal operations developed were the glass shaping and sizing, fixing the phosphors in the shaped glass, charging the glass shapes with tritium (a radioactive gas), and cutting and sealing the glass vials to contain the tritium. Some of the other related operations that were developed included glass annealing, quality control testing, material handling, and packing and shipping.

The light sources were produced in six basic geometrical shapes. The shapes were cylindrical, rectangular, spherical, button, curved cylindrical, and curved rectangular. The outside diameters varied from one to seven millimeters and the lengths varied from 15mm to 150mm. Special glass working

equipment was used to produce these various shaped parts from glass tubing. The type of source being prepared determined its production rate which varied from 360 to 720 units per hour. After shaping, all glass parts were thermally annealed to remove residual strains in the glass. They were loaded into an oven and subjected to an annealing cycle which consisted of raising the temperature to 550°C and maintaining that temperature for 15 minutes before cooling at a rate not exceeding 10°C per minute.

The phosphor coating system was designed to uniformly deposit a thin layer of phosphor crystals on the inside wall of glass light source units of variable size and configuration. The uniformity of the phosphor coating was of primary importance as it determined the quality of the source and the quantity of light ultimately emitted. The phosphor layer had to be thin enough to pass the light generated within, yet thick enough to absorb a large portion of the beta energy generated by the tritium gas.

The tritium filling system was designed to fill glass light sources with tritium and seal them. Special equipment was developed to handle this sequence of operations. Two pieces of equipment were used for tritium filling. A 16-head rotary index filling unit and a six-head inverted rotary index filling unit were used for filling non-pressurized and pressurized sources respectively.

The filling of the light sources involved a minimum of operator responsibilities because of the design of the equipment. The filling operation involved taking the glass parts from storage and placing them into the loading port of one of the filling machines. The glass parts were then subjected to a sequence of automated operations where the glass parts are leak checked, evacuated, filled with tritium gas, and sealed by the operator. The production rates were 30 and 360 sources per hour for the 6-position and 16-position machines respectively.

Sealing of the filled light sources was accomplished by one of two methods, either torch sealing by hand, or laser sealing by use of the laser sealing fixture. A specially designed piece of equipment held and moved the filled sources so that a CO_2 laser could cut and seal parts to the desired length. This system was used mainly on small parts which were difficult to seal using a torch. Torch sealing by hand was accomplished by the use of a miniature natural gas torch and was required for the production of odd-shaped source configurations. Important sealing parameters were identified and optimized sealing was achieved in the range of 2-8 seconds.

The light sources were tested by three different techniques: (1) visual/dimensional, (2) luminance, and (3) liquid scintillation.

The pilot line and procedures were verified by a limited production run which produced 11,900 individual sources in ten different sizes. Figure 1 is a schematic of the manufacturing process that was developed.

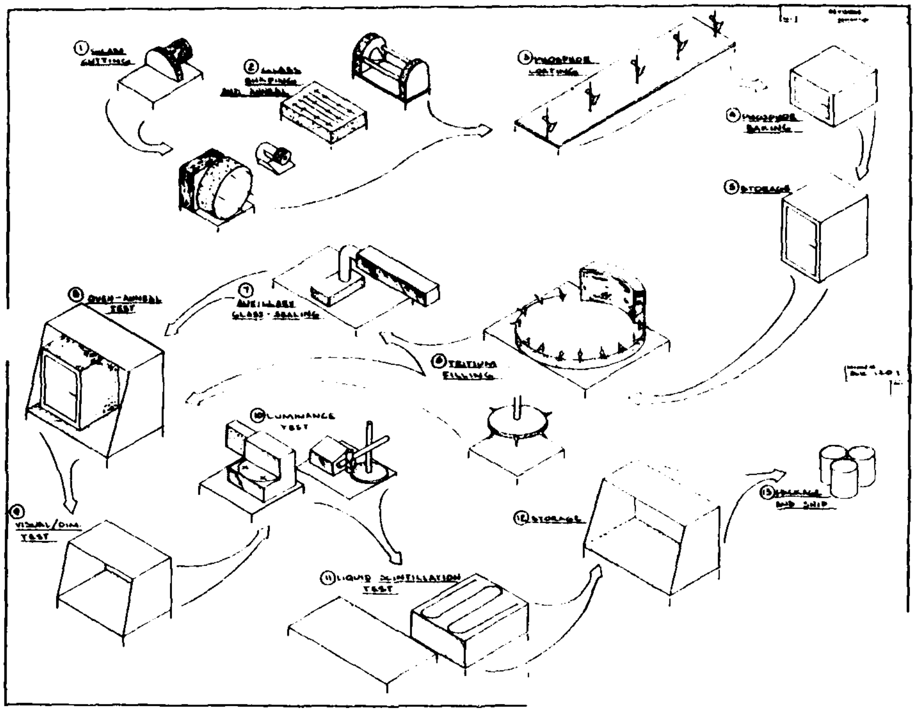

Figure 1 - Schematic of the manufacturing process developed

BENEFITS

Improved qualities in dimension, luminosity, and tritium containment will be available from the pilot production line. Improved luminosity specifications will improve the reliability of the end items performance and reduce the frequency of repair or replacement in the field.

IMPLEMENTATION

The equipment is currently stored at Letterkenny Army Depot while a new start action is being processed for its installation and operation.

MORE INFORMATION

More information may be obtained from Mr. Rober C. McMillan, USAMERDC, Ft. Belvoir, VA, AV 354-5133 or Commercial (706) 664-5133. A final technical report prepared by the contractor titled, "Pilot Plant Facility for the Production of Tritium Radioluminous Sources," number 675 AA-49, 31 Aug 76, R.G. Doda, et al., is available from the DTIC to qualified users.

Summary Report was prepared by Andrew Kource, Jr., Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 774 3580 and 776 3580 titled, "Fuel Cell Stack Production" were completed by the US Army Mobility Equipment Research and Development Command in September 1977 at costs of $196,321 and $235,000 respectively.

BACKGROUND

Fuel cells are electrochemical power conversion units which are being considered as alternatives to batteries for long term, low power, remote applications. The production of fuel cell components is a relatively new field of endeavor and is a technology which is in the preliminary stages. Large quantity production of small fuel cell stack is not commercially available and very few companies are capable of even small quantity productions. Problems in manufacturing fuel cells included processing methods which require large labor outlays, a limited number of material suppliers, and the use of technology which may be replaced as new developments are made in the research area.

SUMMARY

The intent of this effort was to improve the process of manufacturing fuel cells so that the participating contractor, as well as other contractors, could set up an improved production plant for fuel cell manufacturing.

A process for the manufacture of phosphoric acid (H_3PO_4) fuel cell stacks in the 0.4 square feet range was developed under these projects. Major components are bipolar plates, matrices anodes, and cathodes.

Electrodes, matrices, and gas distribution plates were produced and tested during this effort as well as 2, 10, and 35 cell fuel cell stacks. High pressure molding, sheet molding, rolling, sintering, laminating, heat treating, drying, and cutting are some of the techniques involved in the manufacturing of fuel cell components. This effort included a conceptual design for producing 100 fuel cell stacks per month along with equipment and manpower estimates. However, it was determined that performance of the manufactured fuel cell stacks was somewhat lower than contract goals and the exact reasons for this are unresolved. Also, at the present time, fuel cell technology has advanced to the point where this effort's component improvements may be obsolete. Multi-million dollar funding, from such sources as the Department of Energy and the Electric Power Research Institute, for component research and development have provided many new directions and advances in the fuel cell fields.

BENEFITS

The anticipated benefits of developing an improved manufacturing process for fuel cells under this effort were not realized. This was due to the rapidly expanding area of knowledge in fuel cell materials, compositions, procedures, manufacture, and operation gained by other subsequent larger dollar fundings.

IMPLEMENTATION

The results of this MMT effort have not been implemented due to other technological advancements in the state-of-the-art.

MORE INFORMATION

Additional information on this effort is available from Mr. Richard Jacobs, MERADCOM, Fort Belvoir, VA, AV 354-5361 or Commercial (703) 664-5361. Reference technical report AD A042315 titled, "Fuel Cell Stacks."

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

APPENDIX I

ARMY MMT PROGRAM OFFICES

ARMY MMT PROGRAM REPRESENTATIVES

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IBEA US Army Industrial Base Engineering Activity ATTN: DRXIB-MT, Mr. James Carstens Rock Island, IL 61299	C: 309 794-5113 AV: 793-5113
ARRADCOM US Army Armament R&D Command ATTN: DRDAR-PML, Mr. Donald J. Fischer Dover, NJ 07801	C: 201 328-6714 AV: 880-6714
ARRCOM US Army Armament Materiel Readiness Command ATTN: DRSAR-IRB, Mr. August Zahatko Rock Island, Arsenal Rock Island, IL 61299	C: 309 794-4458/3730 AV: 793-4458/3730
AVRADCOM US Army Aviation Systems R&D Command ATTN: DRDAV-EXT, Mr. Robert Vollmer 12th & Spruce Streets St. Louis, MO 63166	C: 314 268-6476 AV: 698-6476
CERCOM US Army Communications & Electronics Materiel Readiness Command ATTN: DRSEL-LE-R, Mr. Martin Ides Fort Monmouth, NJ 07703	C: 201 532-4950 AV: 992-4950
CORADCOM US Army Communications R&D Command ATTN: DRDCO-PPA-TP, Mr. Sam Esposito Building 2700 Fort Monmouth, NJ 07703	C: 201 535-4262 AV: 995-4262
ERADCOM US Army Electronics R&D Command ATTN: DELET-R, Mr. Joseph Key Fort Monmouth, NJ 07703	C: 201 535-4829 AV: 995-4829
MERADCOM US Army Mobility Equipment R&D Command ATTN: DRDME-UPE, Mr. R. Goehner Fort Belvoir, VA 22060	C: 703 664-5530 AV: 354-5530

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US Army Missile Command	
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